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Comparison of Alternative Manure Management Systems: Effect on the Environment, Total Energy Requirement, Nutrient Conservation Contribution to Corn Silage Production and Ecomonics

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COMPARISON OF ALTERNATIVE MANURE MANAGEMENT SYSTEMS-

Effect On The Environment, Total Energy Requirement, Nutrient Conservation, Contribution To Corn Silage Production And Economics

by

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16. ABSTRACT

This study compares alternative dairy manure management systems operated under full scale commercial conditions. The study investigates weight of manure handled per cow per year, labor and energy requirements, effect on the environment, nutrient conservation, corn silage production and total annual operating costs.

The dairy production facility used was a confinement stall barn at the Agway Farm Research Center, Tully, New York. The barn included 60 tie stalls with rubber mats and grates over the gutters. Wood sawdust and shavings were used for bedding throughout the study at an application rate averaged 0.027 m^3 per cow per day.

Provisions were made to handle the manure from the barn in three ways: 1) directly into a spreader for daily spreading, 2) by gravity into a liquid manure storage tank for spring application and immediate plow down, 3) hydraulic ram to a roof-covered above-ground manure storage for spring and fall spreading.

Results of the study show that a manure storage system can reduce annual labor requirements by 65 percent and fuel requirement by 60 percent or more, compared to daily spreading. Stored manure, applied in the spring, and promptly plowed down produced 19 to 29 percent more corn silage than daily spread manure. The study shows daily spreading of manure to be the least cost system for herds up to approximately 60 cows. A roof-covered semisolid manure storage and handling system is a lower cost system for herds above 60 cows.

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in ground water and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for controlling pollution from petroleum refining and petrochemical industries; and for managing pollution resulting from combinations of industrial/industrial and industrial/municipal wastewaters.

This project was initiated to critically investigate several alternative manure management systems and land application methods for dairy farms. The study compared the management systems and application methods in terms of the effect on the environment, air and surface and ground water, the total energy required by each, the nutrient conservation offered by each and the overall economics, including production of corn silage. The results indicated that storing manure in it's as-produced state and applying it in the spring with immediate incorporation was the most effective overall system when all factors were considered. This conclusion will provide the basis for a management change on many dairy farms which will greatly reduce the pollutants leaving the farm and reduce the overall operational expense now being incurred by the farm. The information will be useful in the development of modifications for existing Best Management Practices for animal wastes now being recommended by USDA and EPA.

Clinton W. Hall

Clinton W. Hall, Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

This study compares alternative dairy manure management systems operated under full scale commercial conditions. The study investigates weight of manure handled per cow per year, labor and energy requirements, effect on the environment, nutrient conservation, corn silage production and total annual operating costs.

The dairy production facility used to study alternative manure management systems was a 13.41 m x 43.89 m confinement stall barn at the Agway Farm Research Center, Tully, New York. The insulated, mechanically ventilated barn included 60 tie stalls (cows positioned tail to tail) with rubber mats and grates over the gutters. Wood sawdust and shavings were used for bedding over the rubber mats throughout the study. Application rate averaged 0.027 m^3 per cow per day, or approximately 5.9 kilograms.

Only lactating Holstein cows were housed in the barn during the four year study (average population of 47). Cows were fed a total mixed ration with corn silage the basic forage input. Average milk production per cow was 27 kilograms per day which equates to an annual production of 9,855 kilograms.

A chain gutter cleaner was used to collect and discharge manure at the west end of the barn. To complement the study, provisions were made to handle the manure from the barn in three ways: 1) directly into a spreader for daily spreading, 2) by gravity into a liquid manure storage tank for spring application and immediate plow down, 3) by hydraulic ram to a roof-covered above-ground manure storage for spring and fall spreading and immediate plow down.

Results of the study show that a manure storage system can reduce annual labor requirements by 65 percent and fuel requirements by 60 percent or more compared to daily spreading. Stored manure, applied in the spring, and promptly plowed down produced 19 to 29 percent more corn silage than daily spread manure. The study shows daily spreading of manure to be the least cost system for herds up to approximately 60 cows. A roof-covered semisolid manure storage and handling system is a lower cost system for herds above 60 cows.

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SECTION 1

INTRODUCTION

Manure is a by-product of all milk production systems, and it has significant value. Each dairyman has a constant supply of this valuable source of plant nutrients which represents a substantial recovery of feed nutrient input. Over the years, dramatic changes in dairy manure management practices have impacted on environmental quality, energy requirement, and crop production efficiency.

During the mid to late 1800's, the popular dairy barn design in the northeast housed animals on the second floor. Manure was stored below the stable. During this period, cows were pastured in summer, housed in winter. One hectare of pasture was required to meet the summer forage needs of one cow. At this stocking rate, the manure dropped on pasture posed no serious pollution hazard in most situations. However, the full fertilizer value of the manure dropped on pasture was not realized because of poor distribution and ammonia volatilization.

Manure dropped in the barn over winter and stored under roof on a gravel basement floor lost few nutrients in cold weather but did pose a potential pollution problem in warm weather from run-off and leaching. Odor and fly breeding were also warm weather problems. This stored manure was usually spring applied and plowed down for corn. A popular rotation was corn, spring grain, and three years in hay or improved pasture. Limestone, manure and rock phosphate would be applied to the corn in this rotation.

This manure management scheme conserved and returned most of the organic matter, phosphorus and potassium to the soil. Indeed, because most dairy farms fed some purchased grain, there probably was a modest net gain to the farm plant nutrients. Crop yield levels, by today's standards, were marginal.

In the mid to late thirties, concerns about milk quality prompted more stringent sanitary regulations. Manure could not be stored in the same building with cows producing class A milk. Energy efficient gravity flow from stable to basement storage no longer qualified.

For thirty years -- from the thirties to the sixties -- many devices and systems were developed to move manure away from the stable, none of which worked very well, especially during sub-freezing weather. Following World War II, fertilizer and fuel costs remained low for twenty years. The value of manure as a fertilizer was minimal during this period. Manure became not a by-product to be used, but a waste to be disposed of.

Daily spreading evolved as the most common method for disposing of manure during this period. And this continues to be true today. Manure is scraped from the stable once or twice a day into a manure spreader which delivers it to, and distributes it on, the field.

During the 1940's and 50's, when fertilizer costs were low, manure was disposed of on the fields closest to the barn during cold weather and hauled to a fallow field during the growing season. Application rates per hectare tended to be high -- even excessive. The use of animal manures as fertilizer and soil conditioners was a popular focus of research by the USDA and land grant colleges during the 1920's and 30's. Following 1939, virtually no research was directed at manure management until the 1960's when environmental concerns prompted studies of the impact of animal manures on streams, lakes, and ground water.

The composition of manure from lactating cows is influenced by several factors, including breed and age of animal, level of milk production and the composition and quantity of feed consumed (Fisher, 1974 and Walsh, 1975). It is estimated that two-thirds of the nutrients consumed by dairy cows is voided in the manure (Salter, 1939 and Walsh, 1975). If manure is not wisely managed, it may contribute to the following types of environmental pollution (Coots, 1975):

- contamination of stream and ground water with soluble organic material, inorganic and organic forms of nitrogen and phosphorus. Water thus polluted can be harmful to humans and animals when consumed in large quantities.
- spread of pathogenic organisms and flies that can be infectious and disturbing to humans and animals.
- offensive odor caused by volatile materials such as ammonia, hydrogen sulfide, and various organic compounds.
- unsightly appearance which detracts from rural amenities.

Guidelines for manure management designed to reduce environmental pollution have been suggested by many. Klausner (1976) and Phillips (1981) advise that winter application of manure, at any rate, should be avoided on areas that drain run-off directly into ponds, lakes or streams. Smith (1977) recommends subsurface injection of liquid manure to reduce odors, insects and visual pollution and to minimize run-off. Casler (1972) reports that the agitation of stored liquid manure which is required to disperse settled particulates also aerates the slurry and is a major factor in producing the extremely offensive odors associated with the application of liquid manure.

There is little reliable data comparing complete manure management systems. Most studies, at best, have compared only parts of systems and these only in terms of one or two important criteria. This study was undertaken to meet the need for long term research comparing complete manure management systems over several operating seasons in terms of a number of criteria important both to commercial dairymen and to society. Costs, energy use, nutrient conservation, efficiency of nutrient utilization and influence on the environment in terms of odor, nitrates in ground water and the biological oxygen demand (BOD) and pollution of streams were measured over three years of dairy farm operation.

In terms of environmental impact, it seems clear that storing manure over winter is clearly to be preferred to the alternative of daily spreading on frozen ground. Further, it was theorized that a storage system that did not involve the addition of water would overcome the more objectionable features of liquid storage. Such a system became feasible with the development of a hydraulic ram capable of moving manure 76 meters underground to bottom-load a wood or concrete storage building.

The objectives of the investigation were:

1. To study four experimental manure management systems over a three year period using the following five treatments:
    - A. Liquid manure stored from October to April with water added, spread in the spring and immediately plowed down (Liquid, Spring).
    - B. Semisolid manure stored from October to April with no water added, spread in the spring and immediately plowed down (Semisolid, Spring).
    - C. Semisolid manure stored from April to October with no water added, spread in the fall and immediately plowed down (Semisolid, Fall).
    - D. Simulated daily spreading of fresh manure. One load spread every two weeks beginning in October until 12 loads were spread, and plowing all immediately after the twelfth load was spread (Daily Spread).
    - E. Inorganic fertilizer, spring applied and immediately plowed down (Fertilizer).
2. To measure differences in the five systems over three operating years in terms of:
    - A. influence on the environment, and
    - B. economic impact.

For purposes of reporting, the investigation is divided into two parts. The small plot study measures the influence of each treatment on the environment (except odor) and the efficiency of each treatment in terms of nutrient utilization for corn production. The commercial scale study measures the influence of the four manure management systems on the environment in terms of odor and the economic impact of each in terms of initial investment, annual operating cost and nutrient conservation.

SECTION 2

CONCLUSIONS

The following conclusions are drawn from this research investigation comparing alternative manure management systems in terms of weight of manure handled per cow per year, labor and energy requirement, nutrient conservation through storage, effect on the environment, corn silage production and operating costs.

WEIGHT OF MANURE HANDLED PER COW PER YEAR

Decreasing the weight of manure to haul offers the potential of decreasing labor, energy and machine use requirements. Further, soil compaction will be reduced by reducing the weight of each load and/or the number of loads hauled over the field. Weight of manure handled per cow per year is influenced by several factors including: breed and size of cow, stage of lactation, level of production, feeding program, bedding used, water added and drying which may occur in storage.

Only lactating Holstein cows were used in this study. Milk production averaged 27 kilograms per cow per day. Manure production averaged 54.3 kilograms per cow per day including 5.9 kilograms of dry sawdust and shavings. Average dry matter of the manure including the bedding was 17.3 percent.

With daily hauling and spreading 19.82 M tons of manure were handled per cow per year. Handling the manure as a liquid required the addition of water to create a 14 percent dry matter slurry resulting in 24.5 M tons of manure handled per cow per year. Had water been added to create a 10 percent dry matter slurry, 34.29 M tons of manure would have been handled per cow per year. Handling the manure as a semisolid through a roof-covered manure storage allowed natural drying and a reduction in weight of 8.9 percent, resulting in 18.06 M tons of manure handled per cow per year.

LABOR AND ENERGY REQUIREMENTS

Daily spreading of manure is a labor and energy intensive operation compared to using a six months storage system. Based on a 100 cow lactating herd and a round-trip haul of 2.4 kilometers, a storage system can reduce annual labor requirements by 65 percent and fuel requirements by 60 percent or more compared to daily spreading.

NUTRIENT CONSERVATION THROUGH STORAGE

Agitating manure to create a pumpable slurry in a liquid manure storage is a primary cause of nitrogen loss through volatilization of ammonia gas. Bucket loading of semisolid manure does not create the same conditions. Average nutrient loss through the liquid manure storage and unloading was 10.3 percent nitrogen, 9.1 percent P_2O_5 and 7.9 percent K_2O. Considerable agitation was required to handle the high solids manure which probably contributed to the nutrient loss, particularly the nitrogen. Average nutrient loss through the semisolid manure storage and unloading was 4.6 percent nitrogen, 6.4 percent P_2O_5 and 6.7 percent K_2O.

ENVIRONMENTAL IMPACT

Animal manures impact the environment in a number of ways. Clearly there are positive benefits to the integration of manure organic matter and soil. However, poorly designed and/or managed systems can cause a negative impact. A key objective of this investigation as to measure and document the impact of the manure management systems studied on the environment. Concentration of nutrients (nitrogen, phosphorus and potassium) and coliform bacteria were measured in the stream water adjacent to the treatment fields, run-off water from the fields and percolation water. Odor was measured by a panel made up of equal numbers of farm and non-farm persons.

Stream Water

The concentration of nitrogen, phosphorus and potassium in stream water appeared related to the stream flow rate. The highest concentrations were measured in late summer when stream flow is minimal. At no time during the study did stream water levels of ammonium or nitrate nitrogen exceed the maximum limits considered safe for potable water (0.5 mg/l NH_3 and 10 mg/l NO_3).

Coliform counts in stream water collected down stream from the experimental site never exceeded those of samples taken upstream from the site. Thus, it seems safe to conclude that the performance of this experiment had no adverse effect on the stream water. The site is well suited to continuing studies of the environmental impact of crop management practices.

Run-off Water

Run-off water provides the best single measure of the influence of the treatments studied on the environment. The treatments can be listed in declining order of merit (from least run off to most run off) as follows: semisolid spring, liquid spring, daily spread, semisolid fall, inorganic fertilizer. These findings are in agreement with reports that the organic matter in manure has a profound effect on reducing run off and subsequent loss of soil. Of the twelve storms resulting in measurable run off, one occurred in July, three in August, six in September, and two in October. Since it is known that organic matter in the soil diminishes over time and that manure organic matter reduces run off, then it is logical to expect that the soils to which manure was spring applied and plowed would have the highest manure organic content and least run off while those to which manure had been applied earlier or not at all would have the lowest manure organic matter content and greatest run off.

Percolation Loss of Nutrients

It was observed that the highest concentration of nitrate nitrogen in percolation water occurred shortly after the application and incorporation of each treatment. All treatments contributed levels of ammonium and nitrate nitrogen to percolation water in excess of established safe limits for drinking water (0.5 mg/l NH_3 and 10 mg/l NO_3). There is reason to believe that in most situations these concentrations will be reduced to safe levels as a result of plant and microorganism uptake, soil retention and dilution by the time the percolate reaches the ground water table.

Odor Control

Common sense management in handling and spreading manure can minimize the odor impact on the environment. Manure storages loaded through the bottom usually form a crust over the top during warm weather and a frozen top layer during cold weather. These conditions prevent the release of any significant odors during the storage period. Odors are released from manure during the loading and spreading operations. Reducing the amount of agitation of liquid manure at the storage will lower the odor level. Loading semisolid manure with a bucket loader disturbs the manure only slightly, thus minimizing odor release. Field spreading for uniform coverage breaks up the manure, thus increasing the release of odor. Early incorporation of the manure into the soil by harrow or plow will control the duration of odor release. Same day incorporation of manure into the soil is not practical with a daily spreading system.

CONTRIBUTION TO CORN SILAGE PRODUCTION

The relative efficiency of the several manure management systems was compared through measuring corn silage production. On average, over the three years of the study, the five treatments can be listed in declining order of merit (from the most efficient to least efficient): spring applied inorganic fertilizer, spring applied semisolid manure, spring applied liquid manure, fall applied semisolid manure and daily spreading manure.

Daily spreading of dairy manure remains the most common practice in the Northeast. Assigning a value of 100 to daily spread, it is possible to calculate the relative value of the other manure management systems. On this basis, storing manure, applying it in the spring, and promptly plowing was 19 to 29 percent superior to daily spreading. Storing manure in the semisolid form (without added water) was 9 percent more efficient than a liquid storage system to which water was added.

Semisolid manure was applied in both spring and fall treatments. The fall application was consistently inferior to spring applications, producing just 84 percent as much corn silage when averaged over the three years of the study. However, the fall application of stored semisolid manure produced more corn silage than the daily spread treatment.

Chemical Analysis of Corn Silage

Both the nitrogen and the phosphorus content of corn silage showed a positive linear relationship to yield ($R = .77$ and $R = .65$, respectively). This supports the use of corn silage yield as a reliable and practical measure of the economic impact of manure management systems compared in terms of nutrient utilization efficiency when the rate of application is less than that needed to produce the highest yield the growing season will support.

ANNUAL OPERATING COSTS AND RETURNS

This study shows daily spreading of manure as the least cost system for herds up to 60 cows. A roof-covered semisolid manure storage and handling system is a lower cost system for herds above 60 cows. A liquid manure storage and handling system will improve profit potential over a daily spreading system with herds above 150 cows, but is not as cost effective as semisolid manure handling.

Calculating annual costs of manure handling systems can be done with a high degree of reliability if performance data and investment data are at hand. Projecting the dollar return through nutrient recovery as crop fertilizer is subjective. Variations in existing soil fertility, soil type, rate of manure application, crops grown and climatic conditions are some of the factors which will influence actual dollar return through fertilizer nutrient recovery. In this study, nutrient recovery from each manure handling system as measured by corn silage yield can be listed in declining order of merit as follows: semisolid manure storage and handling, liquid manure storage and handling, and daily spreading.

SECTION 3

RECOMMENDATIONS

1. Manure from dairy production facilities should be stored in containment structures, loaded from the bottom, unloaded and field spread when field and environmental conditions are favorable and incorporated into the soil the day of application. This management practice will have a net favorable impact on the environment.

2. Dairy manure should be handled as a semisolid (as-produced manure with no water added) through a roof-covered storage to attain least cost operation and minimum soil compaction.

3. Transfer manure into the bottom of storages to minimize odors, nutrient loss, freezing and fly problems during the storage period.

4. Agitation of liquid manure (as produced manure with water added) should occur below the surface of the stored manure to decrease release of objectionable odors and nitrogen loss through volatilization of ammonia gas.

5. Further work is recommended on:

    a. Developing practical equipment to bottom load storages, which will minimize stratification of manure in storage.

    b. Methods of unloading manure storages, which will reduce release of odors and nutrient loss.

    c. Design of lower cost containment manure storages, particularly for small herds.

SECTION 4

SMALL PLOT STUDY

MATERIALS AND METHODS

SITE DESCRIPTION

The experimental field consisted of 6.72 hectares of well drained loam soil (Figure 1) at the Agway Farm Research Center near Tully, NY. The field had a surface slope of 0 to 2 percent, running from north to south. A tributary to Fabius Brook, with a water flow ranging from 15 centimeters to 1 meter deep flows west to east past the southern boundary of the experimental area. The field was divided into five plots approximately one hectare each with soil berms about 6 meters wide and 1 meter high separating and surrounding the plots. Figure 2 shows the dimensions of the experimental field plots drawn to scale.

TREATMENT DESCRIPTION AND PROTOCOL

There were five treatments in this experiment, one treatment per plot. It was the intent to apply 3,472 kilograms of manure dry matter per hectare annually from each of the manure systems. The same amount of $N-P_2O_5-K_2O$ in 3,472 kilograms of fresh manure dry matter constituted the inorganic fertilizer treatment.

Plot 1 -- Liquid Manure, Spring Applied

In April each year, when soil conditions were right for plowing, 34.72 metric tons of stored 10 percent dry matter liquid manure was spread per hectare on Plot 1 which contains 0.99 hectares. The entire plot received a total of 34.74 metric tons of liquid manure per year. A 3,785 liter (3,735 kilograms) liquid manure spreader was used to deliver the nine or ten loads required. Plot 1 was plowed immediately after manure application was completed.

Plot 2 -- Semisolid Manure, Spring Applied

In April each year, when soil conditions were right for plowing, 19.26 metric tons of stored 18 percent dry matter semisolid manure was spread per hectare on Plot 2 which contains 1.02 hectares. A total of 19.8 metric tons was applied to the whole plot area each year. The plot was plowed immediately after manure application.

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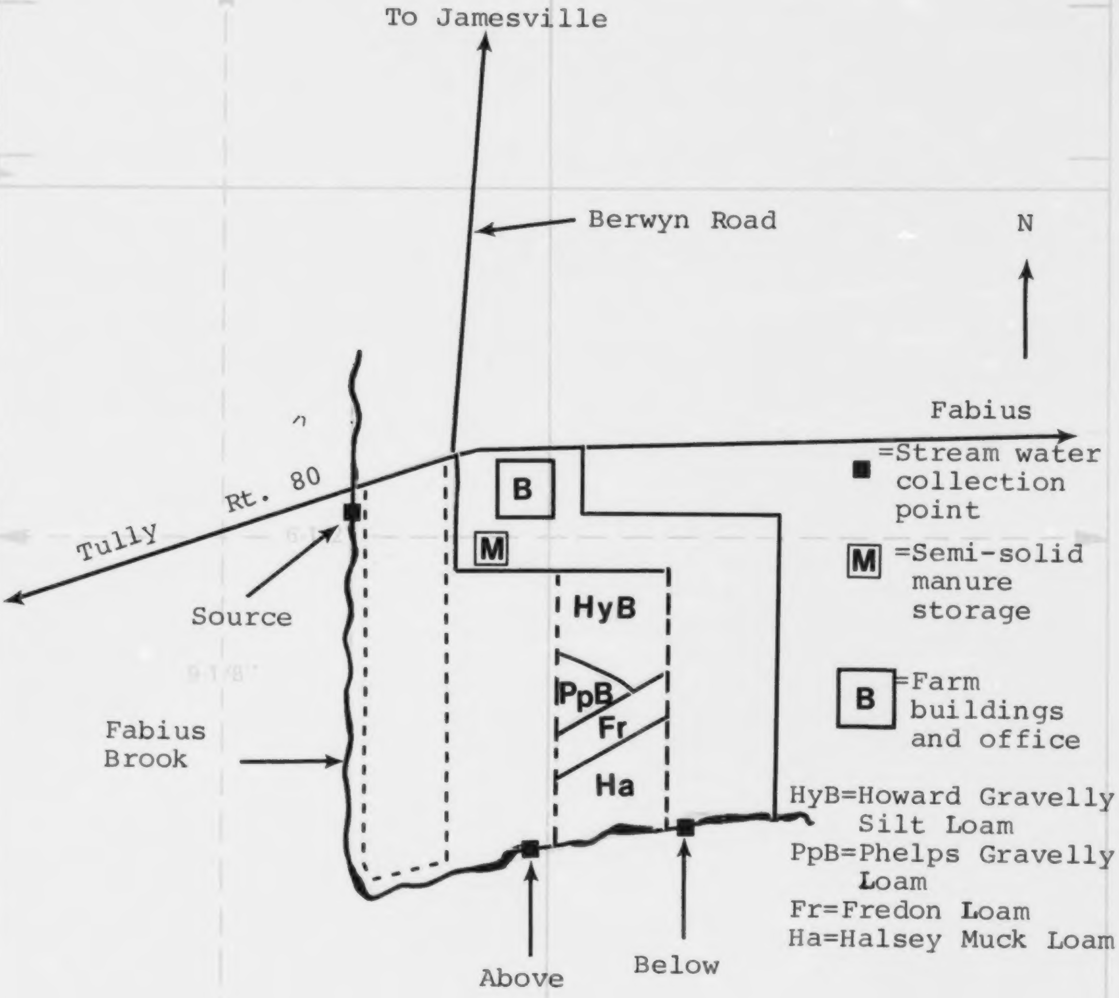
To Jamesville
Berwyn Road
N
Fabius
Rt. 80
Tully
B
M
Source
HyB
PpB
Fr
Ha
Fabius Brook
Above
Below
■ =Stream water collection point
M =Semi-solid manure storage
B =Farm buildings and office
HyB=Howard Gravelly Silt Loam
PpB=Phelps Gravelly Loam
Fr=Fredon Loam
Ha=Halsey Muck Loam

Figure 1. Location of Fabius Brook, stream water collection points, and soil types within the experimental area.

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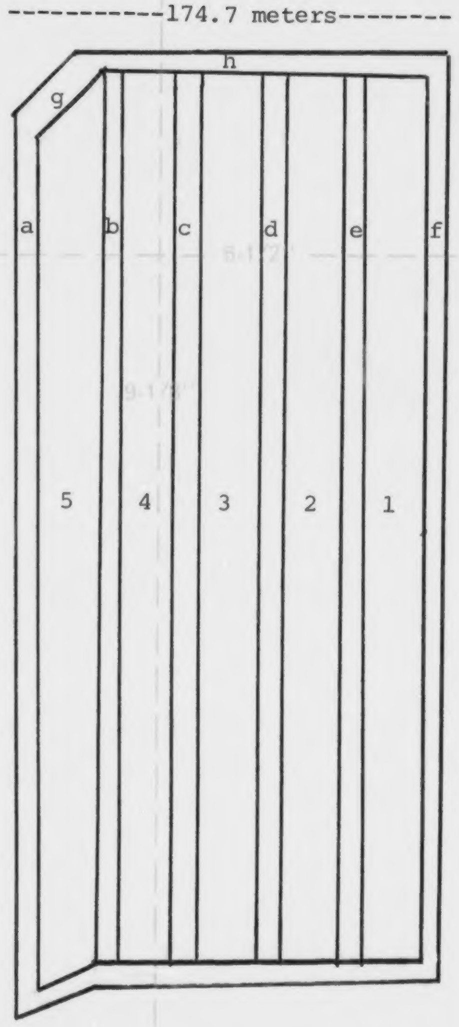
Figure 2:

Field Plot Arrangement
& Dimensions



Scale: 1 centimeter = 30.48 meters

Plot Dimensions

	Meters			Total Area
		Length		
Plot	Width	East	West	(Hectares)
1	26.2	376.4	379.5	0.99
2	26.7	382.5	386.5	1.02
3	25.3	386.5	387.1	0.98
4	26.5	391.7	394.7	1.04
5	26.2	390.1	381.0	1.01

Berm Dimensions

Berm	Width (Meters)
a	7.2
b	7.3
c	7.5
d	6.9
e	7.0
f	7.9
g	15.2
h	7.3

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Plot 3 -- Semisolid Manure, Fall Applied

In October of each year, when soil conditions were right for plowing, 19.26 metric tons of stored 18 percent dry matter semisolid manure was spread per hectare on Plot 3 which contains 0.98 hectares. A total of 18.9 metric tons was applied to the whole plot area each year and was plowed immediately after manure application.

Plot 4 -- Fresh Manure, Spread Daily

Plot 4, containing 1.04 hectares, received twelve separate applications of fresh manure over the 28 week period from October 1 to April 15 of each year. A total of 22.7 metric tons of 16 percent dry matter fresh manure was applied to the entire plot each year. The rate of application was 21.73 metric tons per hectare.

Manure was applied to the sections in an orderly sequence to simulate daily spreading as practiced on most northeastern dairy farms. While applications were called for at two week intervals, adjustments were made in this schedule to work around inclement weather and to assure that all twelve areas of the field had been covered by the time the spring applications of stored manure were made. Plot 4 was spring plowed when all twelve applications had been made. The plot was plowed the same day the spring applied treatments were plowed.

Plot 5 -- Inorganic Fertilizer, Spring Applied

To match the 129-41-77 kilogram rate of N, P_2O_5 and K_2O contained in 3,472 kilograms of fresh manure dry matter, 258 kilograms of 0-15-30 fertilizer plus 402 kilograms (303 liters) of Nitan 32 (a urea-ammonium nitrate solution containing 32 percent nitrogen) was applied per hectare to Plot 5 which contains 1.01 hectares. A total of 261 kilograms of 0-15-30 and 303.8 liters of Nitan 32 was applied to the whole area each year. All fertilizer was spread and plowed on the same day that spring manure treatments were applied and plowed.

All spring applied treatments were made on the same day each year and plowed immediately. The daily spread plot was plowed the same day these spring treatments were applied.

SOURCE OF MANURE

Cow manure used in this experiment was supplied solely from lactating Holstein cows housed in a 60-cow confinement stall barn at the Agway Farm Research Center. Constructed in 1967, the barn was equipped with a 118,745 liter closed concrete liquid manure storage tank. A conventional gutter cleaner was modified to permit delivery of fresh manure: 1) outside to a manure spreader, 2) by gravity into the top of the liquid manure storage tank, or 3) into a hopper from where it was moved by hydraulic ram 73 meters underground through a 30.5 centimeter PVC pipe to the bottom of the new roof-covered semisolid manure storage structure described in detail on page 43.

Fresh manure contained feces, urine, sawdust bedding and a small amount of cleaning water and dumped milk. Fresh manure contained 11 to 12 percent bedding by weight.

EXPERIMENTAL METHOD

To measure uniformity of the experimental field, all five plots were fertilized the same in the spring of 1976. An average rate of 19.6 metric tons per hectare of semisolid manure was applied and plowed down immediately. Two hundred twenty-four kilograms per hectare of a 10-20-10 ammoniated corn starter fertilizer was applied through the planter and 67.2 kilograms per hectare of nitrogen from Nitan 32 was dribbled between the rows when corn was 30 centimeters tall. Yields of 32 percent dry matter corn silage ranged from 29.21 to 32.69 metric tons per hectare reflecting an acceptable level of uniformity (10.6 percent variation) between plots.

Treatments were initiated in October 1976 following corn harvest. The semisolid fall manure (treatment 3) stored from April to October was applied to Plot 3 and plowed immediately. The first of the twelve daily spread applications (treatment 4) was applied to plot 4 the same day.

One full day's production of fresh manure was directed into a spreader one day every two weeks from October to April to provide material for the daily spread treatment. One full day's production of fresh manure was directed into the liquid manure storage tank every two weeks and water added to bring the dry matter content to about 10 percent. The rest of the manure was directed into the hydra-ram hopper and moved into manure storage. Liquid and semisolid stored manure treatments and the inorganic fertilizer treatment were all spring applied on the same day in April each year and immediately plowed down. The entire daily spread plot was plowed on this same day.

Every load of manure delivered to the plots was sampled when loaded into the spreader, providing ten or more samples of each treatment. The actual amount of manure nutrients applied to each plot is recorded in TABLE 1. TABLE 2 shows actual treatment and harvest area per plot each year. The dates of treatment application and incorporation are shown in TABLE 3. Except for the daily spread treatment, the time-lapse between manure application and incorporation by plowing varied from a few to 30 minutes. A five-bottom moldboard plow was used to incorporate the manure to a depth of 20 centimeters.

TABLE 1. Manure, N, P_2O_5 and K_2O Applied to Each Plot, 1976-1979*

Treatment	Parameter Measured	Uniform Test 1976**	Experimental Period				
			1977	1978	1979	Total 1977-79	Average 1977-79
PLOT 1	Percent H_2O	82.52	89.07	89.20	87.26		88.51
SPRING			- - - - - - - - - - -		Kg/Ha	- - - - - - - - - - -	
APPLIED	Fresh Wt.	17,665	35,967	35,323	32,755	104,045	34,682
LIQUID	Dry Matter	3,463	3,932	3,816	4,175	11,923	3,974
MANURE	Organic N	-	58	54	54	166	55
	NH_3-N	-	91	94	96	281	94
	Total N	118	149	148	150	447	149
	P_2O_5	47	70	46	65	181	60
	K_2O	63	85	76	73	234	78
PLOT 2	Percent H_2O	82.42	82.20	81.54	79.47		81.07
SPRING			- - - - - - - - - - -		Kg/Ha	- - - - - - - - - - -	
APPLIED	Fresh Wt.	19,452	19,217	20,319	18,734	58,270	19,423
SEMI-	Dry Matter	3,419	3,420	3,751	3,846	11,017	3,672
SOLID	Organic N	-	55	52	54	160	54
MANURE	NH_3-N	-	63	77	56	196	65
	Total N	115	118	130	112	360	120
	P_2O_5	43	56	49	66	171	57
	K_2O	63	66	68	68	202	67
PLOT 3	Percent H_2O	81.65	80.8	82.66	81.02		81.49
FALL			- - - - - - - - - - -		Kg/Ha	- - - - - - - - - - -	
APPLIED	Fresh Wt.	21,249	20,382	20,543	21,766	62,691	20,897
SEMI-	Dry Matter	3,899	3,913	3,561	4,130	11,604	3,868
SOLID	Organic N	-	55	47	50	152	51
MANURE	NH_3-N	-	72	65	74	211	70
	Total N	128	127	112	124	363	121
	P_2O_5	50	57	40	57	154	51
	K_2O	73	65	73	78	216	72
PLOT 4	Percent H_2O	82.10	82.71	81.61	81.85		82.06
DAILY			- - - - - - - - - - -		Kg/Ha	- - - - - - - - - - -	
SPREAD	Fresh Wt.	21,680	22,901	23,715	25,058	71,674	23,891
MANURE	Dry Matter	3,888	3,959	4,361	4,548	12,868	4,289
	Organic N	-	78	68	66	212	71
	NH_3-N	-	63	82	81	226	75
	Total N	132	141	150	148	439	146
	P_2O_5	53	58	47	67	172	57
	K_2O	81	81	72	90	243	81
PLOT 5	Percent H_2O	81.56	-	-	-	-	-
SPRING			- - - - - - - - - - -		Kg/Ha	- - - - - - - - - - -	
APPLIED	Fresh Wt.	18,140	-	-	-	-	-
INORGANIC	Dry Matter	3,344	-	-	-	-	-
FERTILIZER	Organic N	-	-	-	-	-	-
	NH_3-N	-	-	-	-	-	-
	Total N	110	126	129	132	387	129
	P_2O_5	49	41	41	41	123	41
	K_2O	68	82	76	83	241	80

*Does not include N-P_2O_5-K_2O applied each year from 10-20-10 corn starter.

**In May of 1976, all plots received an application of 17.7 to 21.7 mt/Ha of semisolid manure.

TABLE 2. Actual Area Treated and Harvested Each Year (1976-1979)

		Hectares				
		Plot Number				
Year	Parameter	1	2	3	4	5
1976	Treated	1.00	1.02	0.98	1.05	1.01
	Harvested	0.87	0.88	0.87	0.88	0.86
1977	Treated	1.00	1.00	0.98	0.94	1.01
	Harvested	0.93	0.93	0.94	0.95	0.92
1978	Treated	1.00	1.00	0.98	0.94	1.01
	Harvested	0.92	0.94	0.96	0.96	0.93
1979	Treated	1.00	1.00	0.98	0.94	1.01
	Harvested	0.91	0.92	0.94	0.94	0.93

TABLE 3. Dates Treatments Were Applied and Incorporated Each Year

	Harvest Year		
Treatment*	1977	1978	1979
	- - - - - - - - - Date	- - - - - - - - -	
Spring Applied Liquid	04-12-77	04-14-78	04-24-79
Spring Applied Semisolid	04-12-77	04-14-78	04-24-79
Fall Applied Semisolid	10-12-76	10-20-77	10-24-78
Spring Applied Fertilizer	04-12-76	04-13-78	04-24-79
Daily Spread Fresh:			
1st Application	11-19-76 to	12-15-77 to	11-16-78 to
Last Application	03-31-77	04-02-78	04-12-79
Date Incorporated	04-12-77	04-14-78	04-24-78

*Except for daily spread, all treatments were plowed down immediately after application with no more than 30 minutes elapsing between spreading and plowing. Daily spread manure was plowed under each spring on the same day that spring applied treatments were made. In 1976 all plots received 17.7-21.7 metric tons of fresh manure per hectare on May 10, which was plowed under immediately.

CULTURAL PRACTICES

Seed of the single cross corn hybrid Agway 590X was planted early in May each year with a John Deere six-row plateless max-emerge planter. Agway 10-20-10 ammoniated corn starter fertilizer was applied through the planter and placed 5 centimeters to the side and 5 centimeters below the seed. Pesticides were applied as necessary to control weeds and insects. The crop was harvested shortly after physiologic maturity as evidenced by black layer formation. Cultural practices are documented in TABLES 4 and 5.

TABLE 4. Cultural Practices Used On All Five Plots for the Production of Corn Silage (1976-1979)

	Date		Seeding Rate*	Corn Starter Rate (10-20-10)
Year	Planted	Harvested	Kernels/Ha	Kg/Ha
1976	May 24	October 7	64,200	224
1977	May 17	October 5	64,200	234
1978	May 11	October 3	64,200	212
1979	May 9	September 27	66,700	238

*Agway 590X, a single cross hybrid, was used each year and all seed was treated with Blue Ribbon Protector II (Captan-Thiram) at a rate of 1.62 grams per liter of seed.

TABLE 5. Pesticides Used on All Five Plots (1976-1979)*

	Insecticide**	Herbicides#			
Year	Furadan 10G (Kg/Ha)	Bladex 80W (Kg/Ha)	Lasso 4E (l/Ha)	Atrazine 80W (Kg/Ha)	Booster + E (l/Ha)
1976		2.24	0.76	--	--
1977	14.9	2.24	0.76	2.24	.38
1978	14.6	2.80	0.95	--	--
1979	22.2	2.80	0.95	3.36	.38

*All rates shown are rates of product per hectare.

**Furadan was banded with the seed at planting.

#Bladex and Lasso were applied before emergence of weeds or corn. Atrazine with Booster + E was applied as a postemergence spray on weeds and corn.

HARVEST

A John Deere forage chopper with three row corn head, set to cut at a height of 15 centimeters and roof-covered forage wagons were used to harvest and haul the crop to scales and storage. Two 2 kilogram samples of chopped corn silage were collected from each wagon load and composited to provide one sample per load. Five to eleven loads, averaging 4.5 metric tons were harvested from each plot each year. Every load of corn silage was weighed on a truck scale located between the field plots and the bunk silo storage.

STREAM WATER COLLECTION

Stream water was sampled from the tributary to Fabius Brook west and south of the experimental field (Figure 1). Samples were collected from three sites: "Source" refers to the section of the brook at the northwest corner of field F-4 where it enters the farm. The sampling site was 3 to 6 meters south of New York State highway Route 80. "Above" refers to the section of the brook 9 to 11 meters west of the southwest corner and upstream from the experimental field. "Below" refers to the section of the brook 15 to 18 meters east of the southeast corner and downstream from the experimental field.

During the first year of the project stream water samples were collected quarterly. Starting July 1977, they were collected monthly. At times there was no water at the source sampling site.

RUN-OFF WATER COLLECTION

At the southeast corner of each plot an automatic run-off water collection system was installed (Figure 3). The system, designed by John Whitman of the Agway Technical Center, consisted of a catch basin, a Transite pipe and a water sampler. The catch basin had a capacity of 114 liters. A float switch electrically activated the sampler. The sampler consisted of a timer, a motor and a round rotating disc which held fourteen 3.8 liter wide-mouth plastic jars.

When melting snow or heavy rain resulted in surface run-off, the run-off water flowed into the catch basin. The float switch closed when the water level in the catch basin rose sufficiently to flow through the Transite pipe, activating the timer. At the end of a predetermined time interval (15 minutes), the timer activated the drive motor which moved the first sample jar into position to receive a sample. After five minutes the timer activated the motor once more, rotating the first jar out of the sampling position, but stopping short of placing the next jar in the sampling position. This sequence continued (water collected for 5 minutes, no water collected for five minutes) until all 14 jars had passed the sampling position (at which time the unit was programmed to stop) or the level of water in the catch basin diminished, opening the float switch. Run-off water samples were collected immediately following each storm and promptly delivered to the analytical laboratory.

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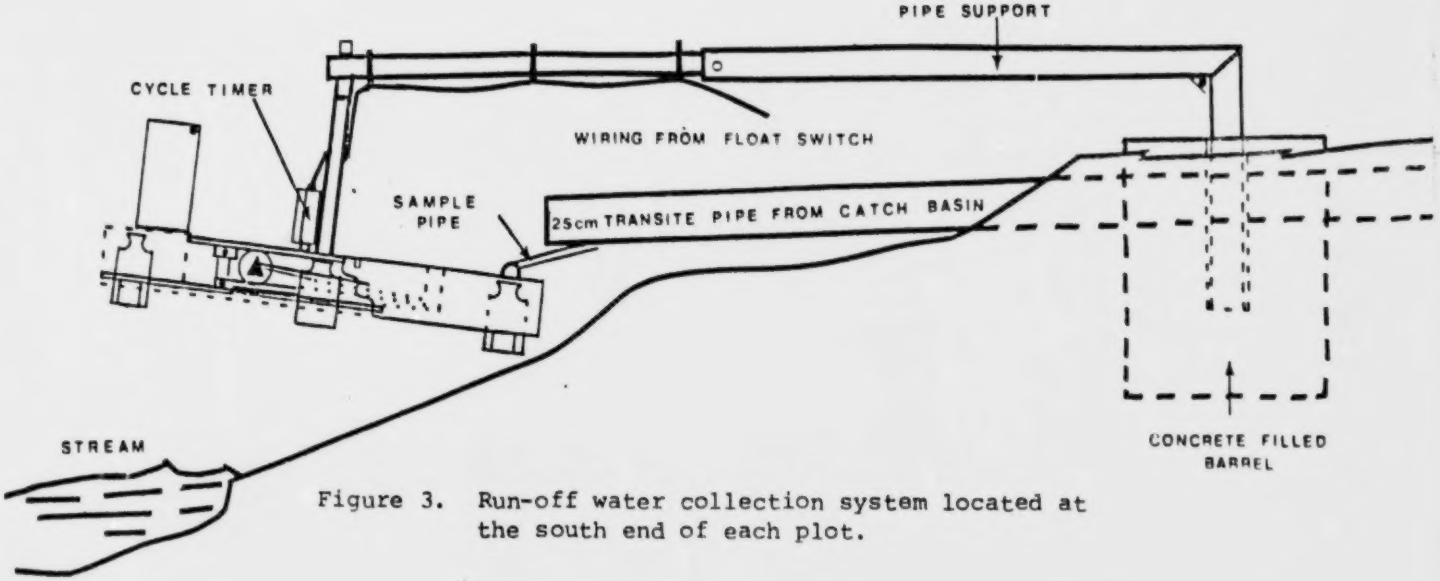
PIPE SUPPORT
CYCLE TIMER
WIRING FROM FLOAT SWITCH
SAMPLE PIPE
25cm TRANSITE PIPE FROM CATCH BASIN
STREAM
CONCRETE FILLED BARREL

Figure 3. Run-off water collection system located at the south end of each plot.

PERCOLATION WATER COLLECTION

Three pressure vacuum soil water sampler lysimeters (Model 1920, Soilmoisture Equipment Corp., Santa Barbara, Calif. 93105) were installed in each plot (Figure 4). The lysimeters were placed in a row from north to south near the center of each plot. Lysimeters were installed to a depth of one to two meters. Depth at some sites was limited by large stones. Three lysimeters were also installed around the semisolid manure storage structure (Figure 5) to monitor any seepage of liquid from the storage. These lysimeters were installed about two meters below the soil surface and one meter lower than the concrete floor of the storage. The distance between the lysimeters and the storage varied from five to eight meters.

Twelve to 24 hours before sampling, lysimeters were energized with a vacuum pump (Pressure-Vacuum Hand Pump Model 1920 KI) to 50-55 centibars of negative air pressure. Water samples were collected in plastic jars.

During the first year of the project, percolation water was sampled quarterly. Starting July 1977, samples were collected monthly. Stream water and percolation water samples were collected on the same day and all samples were delivered immediately to the Agway Technical Center for analysis.

SOIL SAMPLING

Soil samples were taken each fall following harvest and before any treatments were applied. Thirty soil cores were taken from the surface 20 centimeters composited into one sample per plot, analyzed by the Pennsylvania State University Soils Laboratory in 1976 and by the Cornell University Soils Laboratory in 1977, 1978 and 1979.

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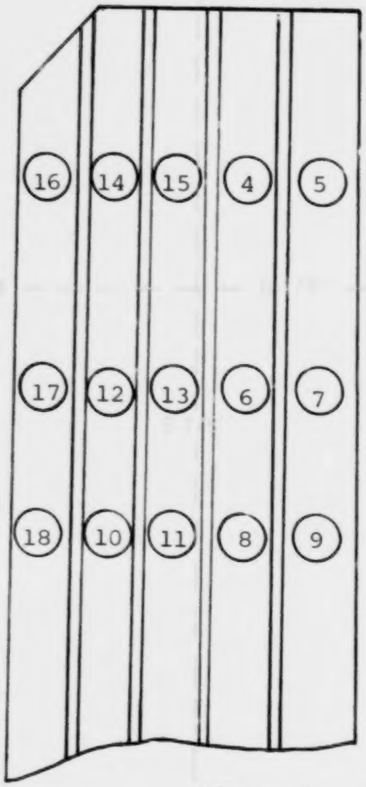

Lysimeter	Depth (Meters)	Distance (meters)	
		From East Border	From West Border
4	1.64	15.16	11.43
5	1.52	9.68	16.49
6	1.93	11.28	15.37
7	1.63	12.62	13.54
8	1.65	6.10	17.50
9	1.30	17.22	8.94
10	1.88	9.14	17.37
11	1.37	15.67	1.04
12	1.47	10.80	15.67
13	1.80	10.36	14.94
14	1.37	16.33	10.14
15	1.40	8.84	16.46
16	1.47	5.66	20.50
17	1.04	11.18	14.99
18	1.84	16.89	9.27

Figure 4. Location of lysimeters in the experimental site.

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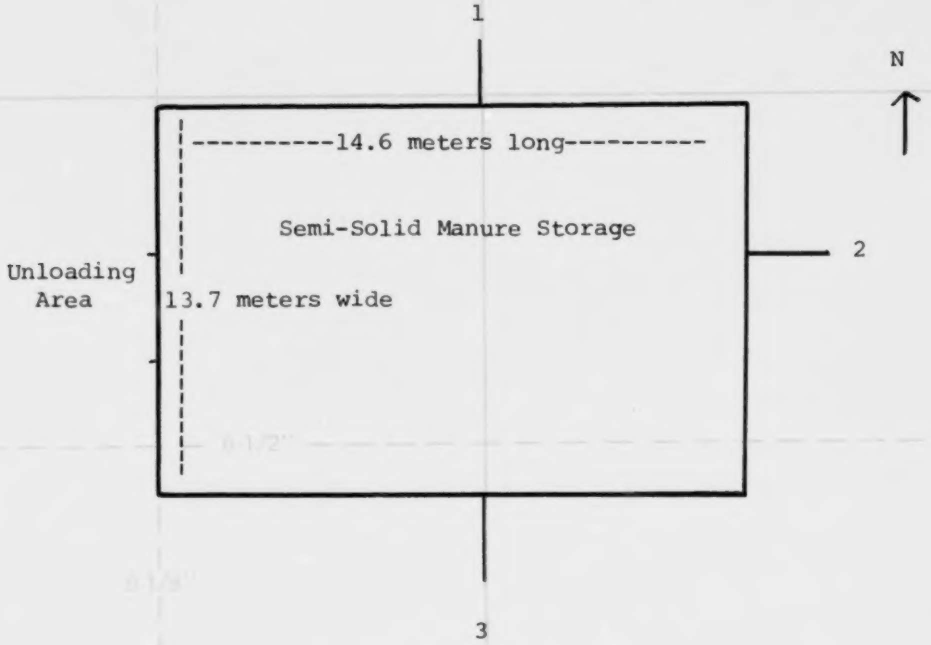
1
N
14.6 meters long
Semi-Solid Manure Storage
2
Unloading Area
13.7 meters wide
3

Lysimeter	Distance From Storage Wall	Lysimeter Depth Below Ground Level	 Storage Bottom
	centimeters		
1	464	184	89
2	765	170	99
3	770	168	102

Figure 5. Location of Lysimeters Around the Semi-Solid Manure Storage

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CHEMICAL ANALYSES

All the samples: water, manure, soil and corn silage were kept as fresh as possible until they were analyzed. The analyses and references for analytical procedures are cited as follows from the 12th Edition of Official Methods of Analysis of the O.A.O.C. (Horowitz, 1975).

Plant Tissue

Moisture -- 48 hours in forced air oven at 65°C

-- 7.003

Protein or Nitrogen -- 7.016

Ether extract -- 7.044

Crude fiber -- 7.050

Ash -- 7.010

Minerals (Ca, P, Mg, Na, K, Cu, Fe, Mn & Zn) -- 7.080 (a)

Modified as follows: Ash 500°C overnight. Analyzed according to "Instruction Manual Model 750 Atom Comp, Jarrell-Ash Division, Fisher Scientific Co., 590 Lincoln St., Waltham, Mass.

Boron -- 3.079

Selenium -- 3.074

Chlorine -- 7.088

Neutral detergent fiber (VanSoest and Wine, 1967)

Modified to omit the use of asbestos.

Fiber -- Butcher's linen and fritted glass crucibles.

ADF -- Whatman 541 filter paper

NDF -- Whatman 541 filter paper or modified California State buchner funnel.

pH -- slurry in water using pH meter.

Water

Stream water and run-off water was analyzed for:

- Total N
- NH_3-N
- NO_3-N
- Organic N
- Total P
- Soluble P
- Particulate P
- Ortho P
- Organic P
- Potassium
- Total Residue
- Cl
- BOD_5
- COD
- Coliform

Percolation water was analyzed for:

- Total N
- NH_3-N
- NO_3-N
- Soluble P
- K_2O
- Cl
- Coliform

Water analysis methods were all as described in "Methods for Chemical Analysis of Water and Wastes" published by the Environmental Protection Agency.

Manure

Dry Matter -- 16 hours in an air oven at 100°C.

Total Kjeldahl nitrogen -- 33.051, AOAC, 1975

Ammonia nitrogen -- 33.057, AOAC, 1975

K_2O and P_2O_5 -- same as minerals under plant tissue.

pH -- same as under plant tissue.

Soil

"Chemical Soil Test", Thomas Grewelling and Michael Peech. Bulletin 960, Cornell University Agricultural Exp. Sta., Ithaca, NY, 1965.

SECTION 5

SMALL PLOT STUDY

RESULTS

EFFECT OF TREATMENTS ON THE ENVIRONMENT

Stream Water

Total nitrogen content of stream water tended to be higher during late summer, every year, than during the fall, winter or spring periods (TABLE 6). This same trend was observed for phosphorus and potassium, although less pronounced. This sequence is probably related to the stream flow rate and represents spring thaw dilution effect. Both ammonium and nitrate nitrogen levels were below the maximum limits considered safe for potable water (0.5 mg/l NH_3 and 10 mg/l NO_3). Ammonium nitrogen reached 0.47 mg/l at the source site on 5/9/79 and nitrate nitrogen reached 7.88 mg/l below the field on 8/11/77.

Coliform counts at all sites were below the 10,000 mpn level at all sampling dates from December 1976 through October 1977 (TABLE 6). Coliform counts rose to 11,000 mpn at the source in November 1977 and reached a high of 46,000 mpn at the "above" site in January 1978. Subsequently, the coliform count dropped below 5,000 mpn at all sites until March 1979 when this pattern was repeated (11,000 at the source and 46,000 mpn at the "above" site). At the end of the trial period, January 1980, all stream water sample sites showed coliform counts of less than 1,000 mpn. At no time did the "below" site exceed the coliform count of the source site but the two were the same on 12/77 (11,000 mpn), 1/78 (24,000 mpn), 3/78 (11,000 mpn), and 3/79 (11,000 mpn).

Thus, it seems safe to conclude that the performance of this experiment had no adverse environmental effect on the stream water and that this experiment site is, therefore, well suited to continuing studies of the environmental impact of crop management practices.

TABLE 6. Effect of the Experiment on the Quality of Stream Water, 1976-1979

Date	Site	Total N	NH_3-N	NO_3-N	Coliform
		----------mg/liter----------			MPN
12/09/76	Source*	2.26	0.01	2.13	4,600
	Above	5.35	0.01	5.00	4,600
	Below	6.46	0.01	6.08	4,600
04/29/77	Source	4.51	0.01	4.38	1,100
	Above	3.51	0.01	2.88	1,100
	Below	3.77	0.01	3.63	1,100
07/21/77	Source	6.45	0.03	6.25	290
	Above	2.17	0.03	1.94	36
	Below	6.28	0.04	6.13	210
08/11/77	Source	6.24	0.02	5.63	91
	Above	2.55	0.02	1.94	360
	Below	8.20	0.03	7.88	930
09/14/77	Source	8.57	0.41	7.63	44
	Above	7.32	0.15	6.38	1,100
	Below	6.17	0.02	5.70	240
10/13/77	Source	2.80	0.20	2.45	2,400
	Above	6.23	0.22	5.88	110
	Below	7.20	0.17	6.25	4,600
11/10/77	Source	3.04	-	3.04	11,000
	Above	5.60	0.02	5.13	930
	Below	4.16	-	4.00	2,400
12/15/77	Source	2.43	0.03	2.38	11,000
	Above	3.41	0.05	3.25	11,000
	Below	3.50	0.03	2.88	11,000
01/12/78	Source*	4.90	0.018	4.85	24,000
	Above	5.55	0.017	5.50	46,000
	Below	5.30	0.015	5.25	24,000
02/16/78	Source	3.12	0.016	2.95	910
	Above	4.06	0.015	4.00	2,300
	Below	4.09	0.017	3.63	910

(continued)

*Please refer to Figure 1 and Materials and Methods.

TABLE 6. (continued)

Date	Site	Total N	NH_3-N	NO_3-N	Coliform
		----------mg/liter----------			MPN
03/16/78	Source	3.88	0.01	3.75	11,000
	Above	5.54	0.39	4.00	11,000
	Below	4.44	0.07	4.12	11,000
04/13/78	Source	3.24	0.015	3.13	2,300
	Above	3.21	0.015	3.25	1,100
	Below	3.04	0.020	2.95	360
05/10/78	Source	3.77	0.01	3.25	200
	Above	4.79	0.01	4.20	360
	Below	4.18	0.031	3.63	360
06/15/78	Source	3.376	0.003	3.29	4,600
	Above	3.51	0.003	3.21	430
	Below	3.861	0.003	3.29	2,400
07/13/78	Source	8.773	0.038	2.86	230
	Above	6.133	0.051	3.03	10
	Below	12.045	0.005	2.01	230
08/10/78	Source	5.48	0.02	5.0	1,500
	Above	4.71	0.03	4.0	2,400
	Below	7.56	0.02	6.0	930
09/14/78	Source	--	--	--	--
	Above	2.904	0.064	0.55	230
	Below	4.934	0.036	2.98	2,100
10/12/78	Source	--	--	--	--
	Above	7.147	0.169	0.14	2,400
	Below	12.534	0.112	2.96	230
11/16/78	Source	--	--	--	--
	Above	8.405	0.008	4.58	70
	Below	4.035	0.005	2.87	90
12/13/78	Source	4.497	0.022	4.06	2,100
	Above	5.376	0.013	4.73	900
	Below	4.544	0.016	4.06	400

(continued)

*Please refer to Figure 1 and Materials and Methods.

TABLE 6. (continued)

Date	Site	Total N	NH_3-N	NO_3-N	Coliform
		----------mg/liter----------			MPN
01/11/79	Source	2.993	0.011	2.75	300
	Above	3.005	0.007	2.88	400
	Below	4.61	0.004	4.13	300
02/14/79	Source	3.941	0.007	3.66	1,100
	Above	3.072	0.009	2.81	240
	Below	2.815	0.007	2.50	150
03/05/79	Source	2.366	0.105	0.98	11,000
	Above	3.56	0.186	2.01	4,600
	Below	2.89	0.119	1.38	11,000
03/14/79	Source	3.03	0.05	2.81	2,300
	Above	3.93	0.04	3.61	46,000
	Below	3.73	0.02	3.54	2,300
04/11/79	Source*	2.80	0.01	2.61	2,100
	Above	2.87	0.01	2.71	9,300
	Below	3.15	0.01	2.86	2,300
05/09/79	Source	5.79	0.47	3.06	2,300
	Above	5.77	0.22	3.30	2,300
	Below	7.64	0.06	4.00	300
06/13/79	Source	2.42	0.003	2.15	2,400
	Above	2.554	0.003	2.34	93
	Below	3.08	0.003	2.81	2,400
07/11/79	Source	3.22	0.11	2.09	2,150
	Above	3.43	0.09	2.05	1,150
	Below	2.81	0.02	2.25	1,150
07/17/79	Source	2.83	0.02	2.21	900
	Above	8.71	0.02	1.91	900
	Below	2.85	0.02	2.45	900
08/08/79	Source	3.809	0.013	2.88	2,150
	Above	4.349	0.027	2.99	450
	Below	2.419	0.011	2.10	200

(continued)

*Please refer to Figure 1 and Materials and Methods.

TABLE 6. (continued)

Date	Site	Total N	NH_3-N	NO_3-N	Coliform
		----------mg/liter----------			MPN
09/12/79	Source	2.02	0.13	1.26	200
	Above	2.02	0.13	1.26	200
	Below	3.86	0.06	3.16	150
10/10/79	Source	2.66	0.02	2.59	350
	Above	2.66	0.02	2.59	350
	Below	1.77	0.07	1.60	150
12/12/79	Source*	3.31	0.012	3.04	1,100
	Above	3.057	0.017	2.86	240
	Below	4.286	0.022	4.11	240
01/09/80	Source	3.386	0.005	3.05	1,100
	Above	2.786	0.017	2.45	210
	Below	3.68	0.011	3.46	43

*Please refer to Figure 1 and Materials and Methods.

Run-Off Water

Run-off water probably provides the best single measurement of the influence of the treatments studied on the environment. TABLE 7 records the analysis of run-off water from each plot at each occurrence.

In September 1977, precipitation totaled 20.04 centimeters, the greatest recorded for any month during the study. Rains continued into October setting up soil conditions of near saturation. This led to recoverable run-off from every plot during a two day storm event on October 17-18, 1977. This was the only storm that resulted in run-off from every plot and provided the only opportunity to compare the quality of run-off water between treatments.

While the volume of run-off was not measured, the sampling devices did provide a reliable sample of the water which escaped from the plot as run-off. The content of each sample jar was analyzed separately and is shown in TABLE 7. The average water analysis for each treatment is shown in TABLE 8 for the October 17-18, 1977, storm event.

TABLE 7. Effect of Manure System and Inorganic Fertilizer Application on the Quality of Run-Off Water, 1976-1979

Date Treatment*	Total N	Total Phosphorus	Potassium
	- - - - - - - - - - -	mg/liter	- - - - - - - - - - -
8/1/77			
Liquid, Spring	-**	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	-	-	-
As Produced, Daily	18.10	10.625	453.0
Inorg. Fert., Spring	-	-	-
8/5/77			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	-	-	-
As Produced, Daily	14.77	4.477	728.0
Inorg. Fert., Spring	-	-	-
9/13/77			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	13.84	4.81	15.0
As Produced, Daily	-	-	-
Inorg. Fert., Spring	8.02	2.55	6.8
9/20/77			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	4.96	1.60	5.55
As Produced, Daily	-	-	-
Inorg. Fert., Spring	5.92	2.82	1.05
9/26/77			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	6.26	1.36	4.2
As Produced, Daily	-	-	-
Inorg. Fert., Spring	2.26	1.36	4.9
10/3/77			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	12.66	0.84	5.3
As Produced, Daily	-	-	-
Inorg. Fert., Spring	-	-	-

(continued)

*Denotes form of the manure and time of application and plowing down. Daily spread was plowed down in the spring.

**A - Indicates no run-off collected.

TABLE 7. (continued)

Treatment	Total N	Total Phosphorus	Potassium
		mg/liter	
10/17/77			
Liquid, Spring*	2.42	0.57	4.1
Semisolid, Spring	1.40	0.67	5.9
Semisolid, Fall#	5.32	0.91	8.0
Semisolid, Fall	1.82	0.59	4.1
As Produced, Daily	2.66	0.59	4.1
As Produced, Daily	2.85	0.89	5.5
As Produced, Daily	3.08	0.81	5.4
Inorg. Fert., Spring	2.81	0.90	3.9
Inorg. Fert., Spring	1.53	0.59	3.6
Inorg. Fert., Spring	3.10	0.44	3.3
Inorg. Fert., Spring	1.55	0.54	4.0
Inorg. Fert., Spring	2.12	0.47	3.4
Inorg. Fert., Spring	1.25	0.40	3.1
10/18/77			
Liquid, Spring	14.98	0.61	3.7
Liquid, Spring	1.90	0.61	3.4
Semisolid, Spring	-**	-	-
Semisolid, Fall	1.14	0.36	3.3
As Produced, Daily	-	-	-
Inorg. Fert., Spring	0.80	0.42	2.6
Inorg. Fert., Spring	0.97	0.33	2.7
7/27/78			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	-	-	-
As Produced, Daily	16.14	0.937	5.0
As Produced, Daily	13.54	1.128	21.4
Inorg. Fert., Spring	21.24	1.500	41.5
Inorg. Fert., Spring	15.68	2.626	36.2
Inorg. Fert., Spring	10.94	1.650	22.8
Inorg. Fert., Spring	26.38	1.672	55.5
Inorg. Fert., Spring	7.25	0.985	5.1
Inorg. Fert., Spring	23.65	1.062	3.8
Inorg. Fert., Spring	25.14	1.594	23.0
Inorg. Fert., Spring	17.52	1.219	3.9

(continued)

*Denotes form of the manure and time of application and plowing down. Daily spread was plowed down in the spring.

**A - Indicates no run-off collected.

#Indicates more than one sample jar collected.

TABLE 7. (continued)

Treatment	Total N	Total Phosphorus	Potassium
	- - - - - - - - - - -	mg/liter	- - - - - - - - - - -
8/7/78			
Liquid, Spring*	-**	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	-	-	-
As Produced, Daily	-	-	-
Inorg. Fert., Spring	17.43	3.310	9.2
9/11/78			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	-	-	-
As Produced, Daily	-	-	-
Inorg. Fert., Spring#	3.88	3.401	7.4
Inorg. Fert., Spring	5.79	3.614	7.7
9/19/78			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	-	-	-
As Produced, Daily	-	-	-
Inorg. Fert., Spring	14.31	4.190	1.7
Inorg. Fert., Spring	8.48	1.300	11.5
Inorg. Fert., Spring	9.06	1.450	37.4
9/17/79			
Liquid, Spring	-	-	-
Semisolid, Spring	-	-	-
Semisolid, Fall	84.86	2.553	4.2
As Produced, Daily	70.66	1.759	6.8
Inorg. Fert., Spring	-	-	-

*Denotes form of the manure and time of application and plowing down. Daily spread was plowed down in the spring.

**A - Indicates no run-off collected.

#Indicates more than one sample jar collected.

TABLE 8. Effect of Manure System and Inorganic Fertilizer Application on the Quality of Run-Off Water From a Single Storm Event, October 17-18, 1977

Treatment	No. of Jars	Total N	Org N	NH_3	NO_3	Total P	K	BOD_5	COD	Coliform
		mg/liter								mpn
Liquid, Spring	3	3.10	1.66	.21	1.23	.60	3.97	11.2	40.3	40,413
Semisolid, Spring	1	1.40	1.09	.18	.13	.67	5.90	1.5	35.0	110,000
Semisolid, Fall	3	2.76	1.67	.11	.98	.62	5.13	7.33	42.9	73,700
Daily Spread	3	2.86	2.03	.26	.62	.79	4.5	1.43	56.8	110,000
Inorganic Fertilizer	8	1.77	.96	.22	.59	.51	3.33	4.48	26.2	75,650

Among the spring plowed treatments, daily spread and liquid manure treatments lost considerably more total nitrogen to the runoff water (2.86 and 3.10 mg/l respectively) than the semisolid treatment (1.40 mg/liter). The semisolid fall treatment had been applied and plowed down on October 12, just five days before this storm event. It contributed 2.76 mg/liter of total N to the run-off water. Conversely, the semisolid and daily spread treatments contributed somewhat more phosphorus and potassium to the runoff water than the liquid manure treatment.

Run-off occurred on the spring applied semisolid manure plot just once and on the spring applied liquid plot just twice, compared with four times for daily spread, seven for fall applied semisolid, and ten for the inorganic fertilizer treatment. These findings are in agreement with reports that the organic matter in manure has a profound effect on reducing runoff and subsequent loss of soil (Salter, 1939). Of the twelve storms resulting in measurable runoff, one occurred in July, three in August, six in September and two in October. Since it is known that organic matter in the soil diminishes over time and that manure organic matter reduces run-off, then it is logical to expect that the soils to which manure was spring applied and plowed would have the highest manure organic content and least run-off while those to which manure had been applied earlier or not at all would have the lowest level of organic matter and greatest runoff.

The treatments compared can be listed in declining order of merit (i.e., from least run-off to most run-off) as follows: semisolid spring, liquid spring, daily spread, semisolid fall, inorganic fertilizer.

Percolation Loss of Nutrients

Average nutrient concentration of percolation water, although complex to interpret, can be used to compare land treatments if the variability encountered from one collection to the next is accepted. Above certain established levels, nitrate and ammonium nitrogen in water are considered hazardous for human or livestock consumption. The upper limit for drinking water is 10 mg/l for nitrate nitrogen and 0.5 mg/l for ammoniacal nitrogen. Samples taken from the inorganic fertilizer plot exceeded those parameters with a three year average concentration of 19.39 mg/l of ammoniacal N and 19.06 mg/l of nitrate N (TABLE 9). The fall applied semisolid manure plot averaged 0.15mg/l ammoniacal N and 6.57 mg/l nitrate N, well within accepted levels. The other three systems averaged 1.24 to 1.41 mg/l ammoniacal nitrogen, all slightly exceeding the upper limit. The three year average values for nitrate nitrogen exceeded the safe limit for daily spread manure and for inorganic fertilizer with values of 20.85 and 19.06 mg/l, respectively. Percolation water samples collected from the other three plots and from near the manure storage structure were all below 7 mg/l nitrate nitrogen.

It was observed that the highest concentrations of nitrate nitrogen in percolation water occurred shortly after the application and incorporation of each treatment. The frequency of percolation water concentration falling below or exceeding safe nitrogen levels during the experimental period is shown in TABLE 10. In terms of ammonium nitrogen content, the fall applied semisolid manure plot had an 11% chance of equalling or exceeding the 0.5 mg/l limit and the four other treatments had a 30 to 36 percent chance. For nitrate nitrogen, the inorganic fertilizer treatment resulted in a 78% chance of equalling or exceeding the 10 mg/l limit; daily spread had a 36 percent chance and the other three treatments had an 11 to 17 percent chance.

While all treatments included in this study contributed concentrations of ammonium and nitrate nitrogen to percolation water in excess of established safe limits for drinking water, these concentrations will usually be reduced to safe levels as a result of plant uptake, use by microorganisms and dilution by the time this percolation water reaches the ground water table (Smith, Concannon). The application of dairy manure to the soil continues to be the most practical method of utilization.

Precipitation

The relevant weather data is summarized by month in TABLE 11. No consistent trend or relationship between nutrient content of percolation water and time or amount of precipitation was observed.

In general, 1.42 centimeters more of precipitation was required to induce measurable run-off (TABLE 12). However, there was no correlation between the number of run-off water sample jars filled (a crude measure of runoff volume) and the amount of precipitation. Snow melt induced no runoff from any plot over the three year period of the study.

TABLE 9. Effect of Manure System and Inorganic Fertilizer Application on the Quality of Percolation Water

Treatment		Total N	Organic N	NH_3-N	NO_3-N
		- - - - - -	- - - - - mg/l	- - - - - -	- - - - - -
Liquid Spring*	Average	11.7	6.62	1.29	4.72
	Maximum	27.49	25.86	10.35	14.20
	Minimum	2.03	1.55	.01	.41
Semisolid Spring	Average	17.04	11.24	1.41	6.05
	Maximum	46.09	43.17	7.94	20.70
	Minimum	.40	.38	.01	.02
Semisolid Fall	Average	15.43	9.825	.15	6.57
	Maximum	51.76	43.89	.81	16.25
	Minimum	2.68	1.50	.01	.26
As Produced Daily Spread	Average	35.57	16.48	1.24	20.85
	Maximum	133.85	62.96	9.12	133.80
	Minimum	1.56	.33	.01	.05
Inorganic Fertilizer Spring	Average	53.57	24.47	19.29	19.06
	Maximum	177.08	114.71	176.60	70.00
	Minimum	12.18	.44	.01	4.00
Near Manure Storage Area	Average	9.53	5.10	1.97	3.19
	Maximum	46.02	41.45	15.12	44.40
	Minimum	.32	.04	.01	.01

*Denotes form of manure and time of application and incorporation. The daily spread manure plot was plowed in the spring of each year.

TABLE 10. Frequency of Percolation Water Concentration Falling Below or Exceeding Safe Nitrogen Levels During the Experimental Period, 1976-1979.

	Liquid* Spring	Semi-solid Spring	Semi-solid Fall	As Produced Daily	Commercial Fertilizer Spring
NH_3-N					
Within the Limit**	10	11	8	7	7
Over the Limit#	5	6	1	4	3
% Over the Limit	33	35	11	36	30
NO_3-N					
Within the Limit##	14	14	8	7	2
Over the Limit###	2	3	1	4	7
% Over the Limit	12	18	11	36	78

*Denotes treatment and time of application and incorporation. As produced daily spread manure was spring plowed.

**Below 0.5 mg/l.

#Equal to or greater than 0.5 mg/l.

##Below 10 mg/l.

###Equal to or greater than 10 mg/l.

TABLE 11. Average Monthly Temperature and Total Precipitation at the Agway Farm Research Center, Fabius, NY

Year	Month	Min. Temp.	Max. Temp.	Mean	Total PPT.
		- - - - - - - -	°F - - - - - - - -		- cm -
1976	September	47	66	56	10.33
	October	36	51	44	13.33
	November	26	38	32	6.14
	December	11*	27*	19*	6.75
1977	January	7*	17*	12*	6.95
	February	14	29	22	9.80
	March	28	44	36	11.32
	April	34	55	45	15.08
	May	44	69	56	2.08
	June	54*	61*	62*	7.16
	July	63	80	71	10.28
	August	58*	76*	68*	13.58
	September	53*	66*	60*	20.04
	October	38	53	46	16.20
	November	35	44	40	7.84
	December	18*	29*	24*	14.96
1978	January	9*	23*	16*	15.18
	February	6*	22*	14*	5.74
	March	16	34	25	6.24
	April	32*	42*	37*	6.07
	May	46	64	55	5.61
	June	53*	70*	62*	13.03
	July	57	77	67	8.73
	August	60*	78*	69*	8.00
	September	50*	68*	58*	5.79
	October	36*	55*	46*	9.32
	November	28*	46*	37*	2.97
	December	19*	32*	26*	5.76
1979	January	8*	27*	17*	12.82
	February	-1	19	9	4.92
	March	25	44	34	7.16
	April	32	51	41	7.67
	May	44	66	55	9.06
	June	49	74	61	6.45
	July	54	79	67	7.72
	August	52	75	64	8.94
	September	44	70	57	13.51
	October	40	56	48	10.71
	November	32	50	41	9.88

*Heiberg Forest, Tully, NY data was used for those days when Agway Research Center data was missing.

TABLE 12. The Amount of Precipitation Which Induced Run-Off

Date	PPT(1)	PPT(2)	Number of Run-Off Samples				
			Liquid+ Spring	Semi-Solid Spring	Semi-Solid Fall	As Produced Daily	Inorganic Fertilizer
	- - - cm	- - -					
08/01/77	-	1.42	0	0	0	1	0
08/05/77	2.58	1.65	0	0	0	1	0
09/13/77	10.31	4.74	0	0	1	0	1
09/20/77	10.84	2.46	0	0	1	0	1
09/26/77	1.11	2.43	0	0	1	0	1
10/03/77	3.35	2.26	0	0	1	0	0
10/17/77	6.45	4.54	1	1	2	3	6
10/18/77	4.54	1.54	2	0	1	0	2
07/27/78	86.13	5.10	0	0	0	2	8
08/7/78	2.56	1.90	0	0	0	0	1
09/11/78	4.47	2.31	0	0	0	0	2
09/19/78	8.15	3.35	0	0	0	0	3
09/17/79	67.89	4.39	0	0	1	1	0
Number of Times Run-Off Occurred			2	1	7	5	9

+Indicates form of manure, time of application and plowing down. Daily spread was spring plowed.

PPT(1) - Total precipitation occurring from the end of one run-off event to the beginning of the next.

PPT(2) - The amount of water measured in the precipitation event that caused run-off to occur.

CONTRIBUTION TO CORN SILAGE PRODUCTION

The field plot acreage to which treatments were applied included the entire area enclosed by the berms, except for Plot 4 (daily spread), and was always somewhat greater than the area actually planted to corn and harvested. Because Plot 4 was divided into 12 sectors of equal size for the simulated daily spread treatments, the treatment and harvest areas were virtually the same. TABLE 2 shows the actual size of the treatment and harvest areas for each plot.

TABLE 1 shows the actual quantity of N, P_2O_5 and K_2O from manure and fertilizer treatments broadcast on the experimental plots 1976-1979. It proved to be easier to calibrate the spreader and accurately apply 3,472 kilograms per hectare of manure dry matter from the semisolid spring and fall treatments than from the liquid or daily spread treatments which were more variable in percent of dry matter. The liquid treatment was overapplied by 452 to 831 kilograms per hectare and the daily spread treatment was overapplied by 484 to 1,072 kilograms per hectare.

Corn Silage Production

The relative efficiency of the several manure management systems is compared in the most meaningful way to dairy farmers in TABLE 13. Here, the corn silage produced by 3,472 kilograms per hectare of manure dry matter or 129 kilograms per hectare of inorganic fertilizer nitrogen is recorded. In the first year of the study, 1977, semisolid manure, spring applied, produced more 32 percent dry matter corn silage (51.3 metric tons per hectare) than any other treatment. The inorganic fertilizer treatment produced the most corn silage in 1978 and 1979, producing 38.72 and 39.17 metric tons per hectare, respectively. Among the manure management systems, semisolid manure, spring applied, produced the most corn silage in 1977 and 1979 while liquid manure, spring applied, produced the most in 1978. The daily spread manure management system produced the least corn silage each of the three years of the study.

On the average over the three years of the study, the five treatments listed in declining order of efficiency as measured by the corn silage produced: inorganic fertilizer 41.90 metric tons per hectare; semisolid, spring, 38.20 metric tons per hectare; liquid, spring, 35.13 metric tons per hectare; semisolid, fall, 31.92 metric tons per hectare; and daily spread, 29.30 metric tons per hectare.

TABLE 13. Total Yield Per Plot of 32 Percent Dry Matter Corn Silage, 1976-1979

Plot	Treatment	Uniform Test 1976	Experimental Period			
			1977	1978	1979	Average 1977-79
		- - - - - - - - - - -	kg/plot	- - - - - - - - - - -		
1	Spring Applied Liquid	28,008	43,269	37,238	30,003	36,837
2	Spring Applied Semisolid	27,040	47,039	34,871	29,485	37,132
3	Fall Applied Semisolid	28,382	39,681	33,227	27,395	33,434
4	Daily Spread	25,823	40,465	33,657	29,176	34,433
5	Spring Applied Fertilizer	26,730	43,192	36,178	37,100	38,823
Five Plot Average		27,197	42,729	35,034	30,632	36,132

TABLE 14. Effect of Treatment on the Yield of 32 Percent Dry Matter Corn Silage (1976-1979)

Plot	Treatment	Uniform Test 1976	Experimental Period			
			1977	1978	1979	Average 1977-79
		- - - - - - - -	metric tons/hectare	- - - - - - - -		
1	Spring Applied Liquid	32.31	41.05	36.84	27.49	35.13
2	Spring Applied Semisolid	30.67	51.30	34.48	28.81	38.20
3	Fall Applied Semisolid	32.69	37.28	33.88	24.59	31.92
4	Daily Spread	29.21	37.23	28.00	23.59	29.61
5	Spring Applied Fertilizer	30.94	47.80	38.72	39.17	41.90
Five Plot Average		31.16	42.93	34.38	28.73	35.35

Daily spreading of dairy manure remains the most common practice in the northeast. Assigning a value of 100 to daily spread, it is possible to calculate the relative value of the other manure management systems as shown in TABLE 15.

On this basis, storing manure, applying it in the spring and promptly plowing was 19 to 29 percent better than daily spreading. Storing the manure in a semisolid form (without added water) was 9 percent more efficient than a liquid storage system to which water is added.

Semisolid manure was applied in both spring and fall treatments. Fall application was consistently inferior to spring applications, producing just 84 percent as much corn silage (31.92 metric tons per hectare) as the spring application (38.20 metric tons per hectare) when averaged over the three years of the study. The fall application of stored semisolid manure, however, was better than the daily spread treatment each year, although by a small margin in 1977.

Chemical analyses of corn silage is shown in TABLE 16. Both nitrogen and phosphorus content of corn silage showed a positive linear relationship to yield (R = .77 and R = .65 respectively). The relationship between nitrogen content and silage yield was linear and that between phosphorus and yield was a quadratic function which maximized at 0.20 percent phosphorus. This supports the use of corn silage yield as a reliable and practical measure of the economic impact of manure management systems compared in terms of nutrient utilization efficiency when the rate of application is less than that needed to produce the highest yield the growing season will support. The potassium content of corn silage was significantly different between years, obscuring any relationship to yield.

TABLE 15. Relative Efficiency of Three Manure Management Systems Compared to Daily Spread, 1977-1979

Plot	Treatment	Yield of Corn Silage* - M. tons/hectare -	Relative Efficiency Compared to Daily Spread - percent -
4	Daily Spread Manure	29.60	100
1	Spring Applied Liquid Manure	35.13	119
2	Spring Applied Semisolid	38.20	129
3	Fall Applied Semisolid	31.92	108
5	Spring Applied Fertilizer	41.90	141

*Adjusted to 32 percent dry matter basis, three year average.

TABLE 16. Effect of Manure and Inorganic Fertilizer Treatments on the Nitrogen, Phosphorus and Potassium Content of Corn Silage, 1977-1979

Year	Treatment**	N	P	K
		- - - -	percent	- - - -
1977	Liquid, Spring	1.34	0.16	1.18
	Semisolid, Spring	1.25	0.11	1.04
	Semisolid, Fall	0.97	0.11	1.29
	As Produced, Daily	1.03	0.11	1.17
	Inorganic Fertilizer, Spring	1.26	0.11	1.30
1978	Liquid, Spring	1.07	0.22	1.12
	Semisolid, Spring	1.17	0.24	1.19
	Semisolid, Fall	1.01	0.25	1.09
	As Produced, Daily	1.03	0.24	1.04
	Inorganic Fertilizer, Spring	1.34	0.23	1.34
1979	Liquid, Spring	1.01	0.18	1.19
	Semisolid, Spring	1.01	0.17	1.07
	Semisolid, Fall	0.94	0.18	1.10
	As Produced, Daily	0.85	0.18	1.16
	Inorganic Fertilizer, Spring	1.14	0.17	1.15

*Reported on a dry matter basis.

**Denotes form of the manure and time of application and plowing down. Daily spread was plowed down in the spring.

SECTION 6

COMMERCIAL SCALE STUDY

OBJECTIVE

Objective of the commercial scale investigation was to compare three manure handling systems in terms of:

1. annual labor requirement per cow
2. annual energy requirement per cow
3. total tons of manure handled per cow per year
4. odor control
5. nutrient conservation through storage
6. total annual operating costs

FACILITIES

The dairy production facility used to study alternative manure management systems on a commercial scale was a 13.41 m x 43.89 m confinement stall barn at the Agway Farm Research Center. The insulated, mechanically ventilated barn included 60 tie stalls (cows positioned tail to tail) with rubber mats and grates over the gutters.

Wood sawdust and shavings were used for bedding over the rubber mats throughout the study. Application rate averaged 0.027 m^3 per cow per day or approximately 5.9 kilograms.

Only lactating Holstein cows were housed in the barn during the 4 year study (average population of 47). Cows were fed a total mixed ration with corn silage the basic forage input. Average milk production per cow per day was 27 kilograms. This equates to an annual production of 9,855 kilograms.

A chain gutter cleaner was used to collect and discharge manure at the west end of the barn. To complement this study, provisions were made to handle the manure from the barn in three ways (Figure 6):

1. directly into a spreader for daily spreading
2. by gravity into a liquid manure storage tank
3. by hydraulic ram to a roof-covered above ground manure storage

Various liquid manure agitator/pumps and front end loaders were used to unload the liquid and semisolid manure storages (TABLES 17 and 18). Several different tractors and manure spreaders were used, for comparison purposes, to haul and field spread manure during the 4 year study (TABLES 19 and 20).

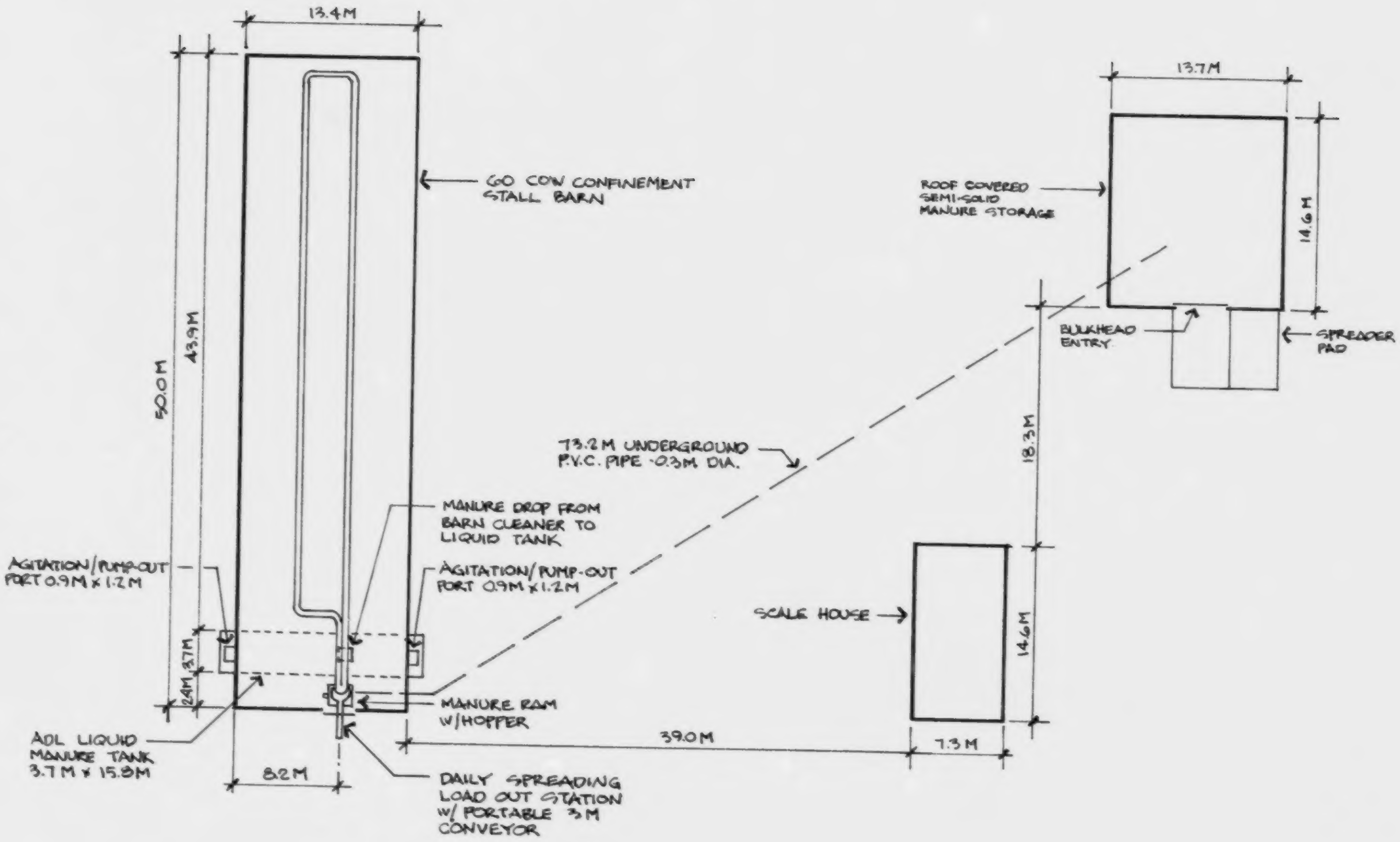
13.4M
60 COW CONFINEMENT STALL BARN
50.0M
43.9M
AGITATION/PUMP-OUT PORT 0.9M x 1.2M
MANURE DROP FROM BARN CLEANER TO LIQUID TANK
AGITATION/PUMP-OUT PORT 0.9M x 1.2M
3.7M
2.4M
MANURE RAM W/HOPPER
ADL LIQUID MANURE TANK 3.7M x 15.8M
8.2M
DAILY SPREADING LOAD OUT STATION W/ PORTABLE 3M CONVEYOR
73.2M UNDERGROUND P.V.C. PIPE -0.3M DIA.
39.0M
SCALE HOUSE
14.6M
7.3M
18.3M
13.7M
ROOF COVERED SEMI-SOLID MANURE STORAGE
14.6M
BULKHEAD ENTRY
SPREADER PAD

Figure 6. Sixty cow confinement stall barn showing daily spreading manure load out station, liquid manure storage tank and semisolid manure storage.

TABLE 17. Agitator/Pumps and Tractors Used To Load Out Liquid Manure From Below Ground Concrete Storage

Trial Number	Equipment Used
Trial L1	One Sahlstrom TG 50 agitator/pump with 44.8 kW John Deere 2440 tractor.
	One Sahlstrom TG 50 agitator/pump with 44.8 kW John Deere 2440 tractor replaced with 94.0 kW John Deere 4430 tractor.
Trial L2	One Sahlstrom TG 50 agitator/pump with 44.8 kW John Deere 2440 tractor.
	One Sahlstrom TG 50 agitator/pump with 44.8 kW John Deere 2440 tractor.
Trial L3	One Sahlstrom TG 50 agitator/pump with 38.8 kW Ford 4000 tractor.
	One Sahlstrom TG 50 agitator/pump with 44.8 kW John Deere 2440 tractor.

TABLE 18. Tractor/Bucket Loaders Used To Load Out Semisolid Manure From Roof-covered Storage

Trial Number	Equipment Used
Trial SS 1	Case 1845, 33.6 kW gasoline, skid-steer loader with 0.67 m^3 bucket.
Trial SS 2	Case 1845, 33.6 kW gasoline, skid-steer loader with 0.67 m^3 bucket.
Trial SS 3	Caterpillar 966B diesel, payloader with 2.68 m^3 bucket (loads 1-24).
	Case 1845, 33.6 kW gasoline, skid-steer loader with 0.67 m^3 bucket (loads 25-39).
Trial SS 4	New Holland L-778, 46.3 kW gasoline, skid-steer loader with 0.59 m^3 bucket.
Trial SS 5	Bobcat 825, 31.3 kW, diesel skid-steer loader with 0.57 m^3 bucket.
Trial SS 6	International Harvester 484, 44.8 kW diesel skid-steer loader with 0.76 m^3 bucket.
Trial SS 7	Bobcat 825, 32.8 kW diesel, skid-steer loader with 0.38 m^3 bucket (loads 1-10).
	Case 1845, 33.6 kW diesel, skid-steer loader with 0.67 m^3 bucket.
Trial SS 8	Bobcat 825, 32.8 kW diesel, skid-steer loader with 0.69 m^3 bucket.

TABLE 19. Spreaders and Tractors Used To Haul and Spread Liquid Manure From Storage

Trial Number	Equipment Used
Trial L1A	3785 liter Waymark liquid spreader with 69.4 kW Oliver 1850 tractor.
Trial L1B	5678 liter Holtz liquid spreader with 91.8 kW John Deere 4520 tractor.
Trial L2A	3785 liter Waymark liquid spreader with 69.4 kW Oliver 1850 tractor.
Trial L2B	5678 liter Holtz liquid spreader with 91.8 kW John Deere 4520 tractor.
Trial L3A	5792 liter Martin S-1666 spreader with 69.4 kW Oliver 1850 tractor.
Trial L3B	8487 liter Martin S-1678 spreader with 94.0 kW John Deere 4430 tractor.

TABLE 20. Spreaders and Tractors Used To Haul and Spread Semisolid Manure From Storage

Trial Number	Equipment Used
Trial SS 1	2.32 m^3 John Deere 23 spreader with 33.6 kW John Deere 2010 or a 53.7 kW Leyland 272 tractor. 5.49 m^3 International Harvester 580 spreader with 69.4 kW Oliver 1850 tractor. 4.56 m^3 Badger BN240 spreader with 59.7 kW International Harvester 826 tractor. 4.25 m^3 New Holland 676 spreader with 53.7 kW International Harvester 706 tractor. 4.64 m^3 New Idea 218 spreader with 59.7 kW John Deere 4030 tractor.
Trial SS 2	5.49 m^3 International Harvester 580 spreader with 69.4 kW Oliver 1850 tractor.
Trial SS 3A	10.39 m^3 Agway 4.9 m tandem axle fertilizer-lime spreader truck (loads 1-24).
Trial SS 3B	5.49 m^3 International Harvester 580 spreader with 69.4 kW Oliver 1850 tractor (loads 25-39).

(continued)

TABLE 20. (continued)

Trial Number	Equipment Used
Trial SS 4A	7.11* m^3 International Harvester 580 spreader with 44.8 kW John Deere 2440 tractor.
Trial SS 4B	8.72 m^3 New Holland 790 spreader with 69.4 kW Oliver 1850 tractor.
Trial SS 5A	7.87 m^3 Martin V-2100 spreader with 69.4 kW Oliver 1850 tractor (first 5 loads until PTO was out of alignment), replaced with 94.0 kW John Deere 4430 tractor (loads 6-28).
Trial SS 5B	7.11* m^3 International Harvester 580 spreader with 94.0 kW John Deere 4430 tractor (IH spreader was used for loads 29-42 when manure was too dry to use Martin V-2100 spreader).
Trial SS 6A	7.87 m^3 Martin V-2100 spreader with 94.0 kW John Deere 4430 tractor.
Trial SS 6B	7.11* m^3 International Harvester 580 spreader with 69.4 kW Oliver 1850 tractor.
Trial SS 7A	7.11* m^3 International Harvester 580 spreader with 69.4 kW Oliver 1850 tractor.
Trial SS 7B	5.97 m^3 International Harvester 595 spreader with 94.0 kW John Deere 4430 tractor.
Trial SS 8A	7.11* m^3 International Harvester 580 spreader with 44.8 kW John Deere 2440 tractor.
Trial SS 8B	5.97 m^3 International Harvester 595 spreader with 44.8 kW John Deere 2440 tractor.

*Capacity of IH 580 spreader increased from 5.49 m^3 to 7.11 m^3 by addition of 5.1 cm x 25.4 cm planks on sides.

DESCRIPTION OF SYSTEMS STUDIED

Three complete manure handling systems were studied using manure from the same herd of Holstein lactating cows housed in a confinement stall barn at the Agway Farm Research Center. The three systems studied were:

1. daily spreading of as-produced manure
2. six months storage of liquid manure and field spreading spring and fall followed by plowing or disking
3. six months storage of semisolid manure and field spreading spring and fall followed by plowing or disking

Daily Spreading Manure Handling System

As-produced manure contained feces, urine, sawdust bedding and, on occasion, a small amount of dumped milk. The only water accumulated in the manure resulted from water slopped out of a water bowl or a leaking valve.

The system included a chain gutter cleaner for collecting and transferring manure to the loading area. A portable 3 meter chain conveyor was used to transfer manure from the end of the gutter cleaner directly into the spreader. A 69.4 kilowatt Oliver model 1850 tractor was used with a 5.49 m^3 International Harvester spreader.

Liquid Manure Storage and Handling System

For this study, liquid manure consisted of as-produced manure including sawdust bedding and with water added as required to create a pumpable slurry.

The system included a chain gutter cleaner which collected and transferred the as-produced manure directly to a liquid manure tank located at the west end of the barn and below grade. The precast concrete tank had interior dimensions of 3.15 meters wide, 15.39 meters long and 2.44 meters deep. Total capacity of the tank was 118,745 liters. Agitation and pump out ports were located in the cover at each end of the tank.

Two tractor powered Sahlstrom agitator/pumps were used to agitate the liquid manure and pump into the liquid spreaders. TABLE 19 lists the liquid spreaders and hauling tractors used.

Semisolid Manure Storage and Handling System

Semisolid manure consisted of as-produced manure including sawdust bedding. There was no water or precipitation added to the manure during the storage and handling periods.

The system included a chain gutter cleaner which collected and transferred the as-produced manure to a steel hopper located at the west end of the barn. The hopper directed the manure to a King solid piston hydraulic ram powered by a 3.73 kilowatt electric motor. The ram transferred the manure underground (below frost line) 73.15 meters through a 30.48 cm PVC pipe to a roof-covered manure storage.

The precast concrete manure storage had interior dimensions of 13.41 meters wide, 14.33 meters long and average depth of 4.11 meters. Total capacity of the storage was 790 m^3. North roof of the storage was covered with galvanized steel and the south roof with translucent plastic panels. The roof was elevated approximately 1.52 meters above the storage walls to allow natural air movement and drying of the semisolid manure. A 3.66 meter wide removable bulkhead was located in the west end to allow entry of tractor loaders and spreaders. Several different front end loaders, spreaders and hauling tractors were used as shown in TABLES 18 and 20.

SECTION 7

EXPERIMENTAL PROCEDURES

COMMERCIAL SCALE STUDY

GENERAL PROCEDURES

For the commercial scale part of this study every effort was made to follow accepted commercial farm procedures in handling manure by each of the three systems. Manure required for the small plot studies, while handled the same as for the commercial scale studies, was not included in the energy and labor measurements.

Several procedures were common to each of the three manure handling systems. Cow days represented by each trial and total milk production were recorded. Volume of sawdust bedding used was recorded daily and density checked monthly. Odometers were installed on the hub of each manure spreader and calibrated to determine distance each unit traveled. Each load of manure was weighed over platform truck scales and recorded. Fuel use for each tractor used for loading or hauling was measured. Labor inputs were intensely monitored and partitioned into elements of loading, weighing, hauling and spreading. The weighing element was subsequently subtracted out of the total cycle time as it would not be done on a commercial basis. Odor evaluations were made for each manure storage handling system using the criteria shown in Appendix A.

Manure samples were taken from the hopper over the hydra ram (Figure 6) to determine the dry matter and nutrient content of the as-produced manure including bedding. The gutter cleaner was operated twice daily to minimize loss of nutrients through volatilization at the barn. The gutter cleaner collected and discharged manure from the 60 cow confinement stall barn for the daily spreading, liquid storage and handling and semisolid storage and handling systems. Therefore, manure samples taken from the hydra ram hopper were considered representative of all three systems.

During the first fourteen months samples were taken monthly. Sampling frequency was increased to bimonthly for the subsequent ten months and then weekly for the last two years of the project. In all cases an AM and PM sample was taken on each sampling day. Sample containers were immediately placed in a refrigerator to keep the sample fresh. All samples were analyzed at the laboratory for dry matter, total nitrogen, ammonia nitrogen, K_2O and P_2O_5, following procedures outlined in the small plot section of this report.

PROCEDURES FOR DAILY SPREADING TRIALS

Most commercial dairies which do not have manure storages remove manure from the barn once daily. Manure is loaded directly into a hauling/spreading vehicle, hauled to the field and spread. Daily spreading trials in this study were conducted accordingly.

Six trials were conducted, each having five days duration. Three of the trials were conducted under winter conditions and three under summer conditions. A 69.4 kilowatt, model 1850 Oliver diesel tractor hauling a 5.49 m^3, model 580 International Harvester spreader were used to haul and spread manure for each of the trials.

For control purposes, the tractor and spreader were not used for any other operations during the trial periods. The tractor and spreader were housed in a machinery shed located approximately 53 meters from the loading station following each day's run. The tractor was filled with fuel at the beginning of each trial. All subsequent fillings and the fill-up at the end of the trial were totaled to determine fuel use.

A portable 3 meter chain conveyor was installed at the end of the gutter cleaner to convey the manure on over the hydra ram hopper to the manure spreader. Cost of the conveyor and energy used by the conveyor were not considered in the economic analysis of this system because the equipment would not be required in a typical commercial installation.

The operation was conducted at approximately 10:00 AM each day. The operator positioned the tractor drawn spreader under the discharge conveyor and started the gutter cleaner and conveyor extension. The operator moved the spreader as required during the loading process. When loading was completed, the operator drove the tractor and spreader to the scale room, approximately 60 meters, to determine gross weight. This element of the operation was timed but not included in labor input calculations. Tare weight for the tractor and spreader was determined prior to the start of the trial. Following weighing of the day's manure production, the operator drove the rig to a pre-selected field, spread the manure and returned the rig to the machinery shed.

Pivot Points For Timing Operation

Partitioned elements of timing included: 1) positioning the tractor and spreader under the discharge conveyor, 2) operating the barn cleaner and moving the spreader during the loading process, 3) weighing the loaded rig, 4) travel time (hauling) to and from field, and 5) spreading.

Time required to position rig under conveyor started when operator left milk room and stopped when gutter cleaner was energized. The second time element, operating gutter cleaner and loading spreader, started when gutter cleaner was energized and stopped when the operator started the rig toward the scale room. Weighing time started at this point and stopped when tractor started forward from scale room. Hauling, or travel time, started when rig left scale room and terminated when rig was back in machinery shed and operator returned to milk room. The final time element, spreading, started when the beaters on the spreader were engaged and stopped when all manure was spread. This element of time was subtracted from the previous element of hauling time to determine actual time required to travel to and from the field.

Data Collection

Data collected included: 1) time data as outlined above, 2) gross and tare weights of each load, 3) fuel consumed by tractor, 4) spreader odometer readings, 5) cow days in trial period, 6) total milk production, and 7) cubic meters of bedding used. Appendix B samples the work sheets used to calculate annual labor and energy requirements for various herd sizes and hauling distances from the raw data.

It was not necessary to take manure samples for nutrient analysis because any nutrient loss between the barn and field spreading (elapsed time of about 30 minutes) would be insignificant. It was judged that such loss would be less than the potential error from sampling and analyzing.

PROCEDURES FOR LIQUID MANURE STORAGE AND SPREADING TRIALS

Liquid manure storage and handling on dairy farms began to gain commercial acceptance in the mid-1960s. Typically, a concrete tank located under the barn floor or at the end of the barn, below grade, was used for storage. Liquid manure trials in this study used similar facilities.

Three trials were conducted under favorable field and weather conditions, simulating a commercial spring or fall unloading of a liquid manure storage. Manure handled was from the same lactating Holstein cows used with the daily spreading trials.

A tractor powered Sahlstrom agitator/pump was used at each end of the 15.24 meter tank to agitate the liquid manure to a uniform pumpable slurry. One of the pumps was used to load the liquid manure spreaders. Various liquid spreaders were used as shown in Table 19.

The operation started at approximately 7:00 AM each day when tractors were hooked to the two agitators. Pre-agitation was conducted for approximately three hours or until a uniform manure slurry was observed in the storage tank. Generally the agitators were left unattended during the pre-agitation. Therefore, zero labor was assigned to this process.

Loading, hauling and spreading of the liquid manure started around 10:00 AM, using two liquid manure spreaders. One of the Sahlstrom pumps was used for loading and both units continued to agitate the slurry between loads.

A sample of manure was taken from each load immediately after the loading process was completed. A long handled dipper was extended midway into the spreader to withdraw a sample and it was placed in a premarked sample container. Sample containers were immediately placed in a refrigerator and transferred to the laboratory at the termination of the trial. Samples from two consecutive loads were composited at the laboratory and analyzed.

After loading, the operator drove the tractor and spreader to the scale room, approximately 50 meters to determine gross weight. This element of the operation was timed but not included in labor input calculations. Tare weight for each rig was taken after the first load in the morning and repeated after every fifth load. Manure was spread on a pre-selected field and plowed or disked in the same day.

Each tractor was filled with fuel at the start of the trial. All subsequent fillings and final fill-ups at the end of the trial were totaled to determine fuel use. Fuel used for agitating and pumping was partitioned from fuel used to haul and spread.

Pivot Points For Timing Operation

Partitioned elements of timing included: 1) agitation of the liquid manure (machine time only), 2) loading time, 3) weighing the loaded rig, 4) travel time (hauling) to and from the field, and 5) spreading.

Agitation began when the two tractors on the agitator/pump units were started and stopped just prior to loading the last load. Pumping time (loading time) was subtracted out to determine total machine time for agitation only. Loading time started when liquid manure was observed coming out the discharge pipe from the pump and stopped when the pump was shifted back to agitation.

Weighing time started at this point and stopped when the tractor started forward from scale room. Hauling, or travel time, started when rig left scale room and terminated when the next loading cycle started. Spreading time started when PTO on hauling tractor was engaged and stopped when all manure was spread. This element of time was subtracted from the previous element of hauling time to determine actual time required to travel to and from the field.

Data Collection

Data collected included: 1) time data as outlined above, 2) gross and tare weights of each load, 3) fuel consumed by each tractor, 4) spreader odometer readings, 5) total milk production, 6) cubic meters of bedding used, and 7) odor evaluation. Appendix C samples the work sheets used to calculate annual labor and energy requirements for various herd sizes and hauling distances from the raw data.

PROCEDURES FOR SEMISOLID MANURE STORAGE AND SPREADING TRIALS

Eight trials were conducted unloading the roof-covered manure storage during the four year study, four in the spring of the year and four in the fall. Manure handled was from the same lactating Holstein cows used with the two previous manure handling systems.

Five box spreaders and one steer-skid loader were used for Trial 1. The storage with six months manure from 57 cows was unloaded in one day. In the second trial the storage with manure from 52 cows was unloaded in 20 hours by one man with one box spreader and one steer-skid loader. In the other six trials two spreader rigs and one loader were used by two operators. Various sizes and types of spreaders, as shown in Table 20 were used for comparison purposes.

Numerous visitors came to the Research Center to observe the new semisolid manure transfer, storage and handling system. During each unloading trial, temporary barricades were erected to direct and keep visitors in safe areas (away from tractor traffic). In addition to safety, it was important that visitors did not interfere with manure loading and hauling operations causing extra labor input.

The unloading operation started at approximately 7:00 AM each day when spreaders and loader were in position at the roof-covered manure storage. The operation continued until 5:00 PM each day, weather and field conditions permitting. Breaks and lunch periods were not included as part of the labor input. Manure was spread on pre-selected fields and plowed or disked in the same day. Labor and energy required for plowing and/or disking was not considered part of the manure handling operation.

Spreader rigs were positioned on a concrete area adjacent to the bulkhead entry to the storage. With chain falls the operators raised the 0.6 meter high bulkhead sections as required to control manure movement to the loading area. Approximately half of the manure in the storage moved to the loading area by gravity where it was bucket loaded into the spreaders. After all bulkhead sections were removed, the bucket loader entered the storage to remove manure and finally the spreader rigs were positioned inside the storage to facilitate loading.

Manure samples were collected from each load. One scoop was taken from each bucket of manure after it was dumped in the spreader and placed in a premarked sample container. This sampling procedure did not interfere with the normal loading operation. The composited samples from each load of manure were immediately placed in a refrigerator and transferred to the laboratory at the termination of the trial. Samples from two consecutive loads were composited at the laboratory and analyzed as previously reported.

After loading, the operator drove the tractor and spreader to the scale room, approximately 30 meters, to determine gross weight. This element of the operation was timed but not included in labor input calculations. Tare weight for each rig was taken after the first load in the morning and repeated after every fifth load.

Each tractor was filled with fuel at the start of the trial. All subsequent fillings and final fill-up at the end of the trial were totaled for the loading tractor and each tractor used to haul a spreader. In trial one, fuel used by tractors used with the five spreaders was combined to determine energy requirement for hauling and spreading. In subsequent trials, fuel used by each hauling tractor was kept separate to determine relative energy efficiency using different size spreaders and tractors.

Pivot Points For Timing Operations

Partitioned elements of timing included: 1) bucket loading, 2) weighing the loaded rig, 3) travel time (hauling) to and from field, 4) spreading, and 5) idle time.

Loading time started when the first spreader rig was in position and tractor shut off. Loading time terminated and weighing time started when hauling tractor started away from loading area. Weighing time terminated when tractor and spreader left scale room. Hauling, or travel time, started at this juncture and terminated when the spreader rig was positioned at the loading area and the tractor was shut off. Spreading time started when PTO was engaged and forward motion began. Spreading time stopped when manure was unloaded. This element of time was subtracted from the previous element to determine actual travel time to and from the field.

Idle time was measured near the end of the hauling cycle. If a spreader rig returned to the storage and could not immediately be positioned at the loading area because another unit had not left, it was stopped at a predetermined line and the idle time recorded. This occurred during trial one because five spreader rigs were operating. In the other trials with one or two spreader rigs used it was not a problem because time required to haul and spread was considerably greater than loading time. Idle time recorded was subtracted out of total cycle time and not included in labor input calculations.

Data Collection

Data collected included: 1) time data as outlined above, 2) gross and tare weight of each load, 3) fuel consumed by each tractor, 4) spreader odometer readings, 5) total milk production, 6) cubic meters of bedding used, and 7) an odor evaluation. Appendix D samples the work sheets used to calculate annual labor and energy requirements for various herd sizes and hauling distances from the raw data.

SECTION 8

RESULTS AND DISCUSSION

COMMERCIAL SCALE STUDY

DAILY SPREADING MANURE HANDLING SYSTEM

During the early part of this century, many dairymen stored manure in a cellar below the barn floor, in a separate structure close to the barn or in stacks just outside the barn. Primary objectives were to conserve nutrients and eliminate the burdensome chore of daily spreading manure under adverse conditions. With the development of tractor power, power take-off driven manure spreaders and relatively cheap purchased fertilizer, dairymen adopted the practice of daily spreading manure. Daily spreading of manure has been a common management practice on most U.S. commercial dairy farms for the last forty years.

Annual Labor Requirement

Annual labor requirement for daily spreading of manure from 100 cows and with a round-trip haul of 2.4 kilometers averaged 296 hours for the six trials (TABLE 21). Winter trials required approximately 18.5 percent more labor than summer trials. Slower hauling, 8.26 kilometers per hour winter vs. 9.61 kilometers per hour summer and slower spreading rates, 0.98 minutes per M. ton winter vs. 0.85 minutes per M. ton summer were primary reasons. Labor required to load manure at the barn was essentially the same, 4.43 minutes per M. ton winter and 4.50 minutes per M. ton summer. The three winter trials averaged 56.7 cows and the three summer trials averaged 47.9 cows.

Labor for loading manure included time required to position spreader under the gutter cleaner and 50 percent of time for gutter cleaner to move manure from barn to spreader. This provided the operator adequate time to move the spreader, as required, during the loading process. The other 50 percent of the time was directed toward other chores.

Herd size affects labor efficiency more with daily spreading than with manure storage systems. Hitching tractor to spreader and positioning under barn cleaner takes approximately the same time for 50 cows as with 150 cows. Hauling time (travel to and from field) takes about the same time for 50 cows as with 150 cows, assuming only one spreader load per day is required. However, time required for barn cleaner to load manure into spreader and time required to field spread (unloading) will vary in direct relation to herd size.

TABLE 21. Annual Labor Requirement To Daily Spread Manure From 100 Cows With Round Trip Haul Of 2.4 Kilometers

Trial	Pay Load M Tons	Minutes Per M Ton Loading	Kilometers Per Hour	Minutes Per M Ton Spreading	Annual Labor Hours
			WINTER TRIALS		
DS 1	3.76	4.93	9.12	0.90	322
DS 2	3.83	4.18	6.53	0.94	345
DS 3	3.39	4.18	9.12	1.09	297
Average	3.66	4.43	8.26	0.98	321
			SUMMER TRIALS		
DS 4	2.59	4.53	8.06	0.83	284
DS 5	2.63	4.43	10.35	0.96	269
DS 6	2.74	4.55	10.43	0.75	260
Average	2.65	4.50	9.61	0.85	271
Average All Trials	3.16	4.47	8.94	0.92	296

Annual Fuel Requirement

Annual fuel requirement for daily spreading of manure from 100 cows and with a round-trip haul of 2.4 kilometers averaged 2,613 liters for the six trials (TABLE 22). The same 69.4 kilowatt Oliver model 1850 tractor and 5.49 m^3 International Harvester spreader were used for all six trials. Winter trials required approximately 82 percent more fuel than summer trials. Cold operating temperatures, engine idling at the barn and increased total operating hours all contribute to the significant increase in fuel consumption in the winter.

Summaries of annual labor and fuel requirements to daily haul and spread as-produced manure direct from barn for each of the six trials are shown in Appendices E1 through E6. These summaries consider herd sizes of 50, 100 and 150 cows. Annual labor and fuel requirements are calculated for round-trip hauling distances of 0.8, 1.6 and 2.4 kilometers.

TABLE 22. Annual Fuel Requirement To Daily Spread Manure From 100 Cows With Round Trip Haul of 2.4 Kilometers

Trial	Pay Load M Tons	Kilometers Per Liter	M-Ton Kilometers Per Liter Hauling & Spreading	Annual Fuel Liters
	WINTER TRIALS			
DS 1	3.76	0.46	1.73	3,248
DS 2	3.83	0.39	1.49	3,986
DS 3	3.39	0.57	1.92	2,873
Average	3.66	0.47	1.71	3,369
	SUMMER TRIALS			
DS 4	2.59	1.04	2.69	1,756
DS 5	2.63	0.92	2.43	2,029
DS 6	2.74	0.98	2.70	1,783
Average	2.65	.98	2.61	1,856
Average All Trials	3.16	.73	2.16	2,613

Odor Control

No attempt was made to evaluate odor during the daily spreading trials as was done with the liquid manure storage and spreading trials and the semisolid manure storage and spreading trials. Experience at the Agway Farm Research Center and observations on commercial dairies indicate that spreading of fresh as-produced dairy manure has not caused serious odor problems. Odor could be a problem if the fresh manure was spread on a hot humid summer afternoon. Practical management practices can avoid this situation.

LIQUID MANURE STORAGE AND SPREADING SYSTEM

Liquid manure handling equipment and storages were introduced in the United States in the early 1960s. Herd sizes were increasing and dairymen were looking for an alternative to the burdensome chore of daily spreading manure. Other factors causing interest in liquid manure storage included: 1) shrinking supply and increasing cost of bedding materials, 2) soil compaction caused by daily spreading under adverse field conditions, 3) nutrient conservation, and 4) possible environmental damage resulting from run off of nutrients when spreading on frozen ground or snow.

Liquid manure storages constructed in the 1960s were typically concrete and located below the floor level of the barn to facilitate transferring manure from the production area to the storage. The liquid manure storage used in this trial was constructed in 1967 and of the type described above. The precast concrete tank had interior dimensions of 3.15 meters wide, 15.39 meters long, and 2.44 meters deep. Agitation and pump out ports were located in the cover at each end of the tank. With this storage shape and dry matter content of manure going into the storage above 17 percent, agitation was very inefficient and fuel intensive.

Annual Labor Requirement

Annual labor requirement for handling manure from storage as a liquid from 100 cows and with a round-trip haul of 2.4 kilometers averaged 140 hours for the six trials (TABLE 23). Farm road and field conditions were more favorable in Trials L2A and L2B than the other four trials. Rough, hilly or wet field conditions affect travel rate adversely resulting in increased labor requirements. Travel rate in Trial L2B was 19.09 kilometers per hour compared to 10.06 kilometers per hour in Trial L1A. Skill of the tractor operator also influences rate of travel.

TABLE 23. Annual Labor Requirement to Handle Liquid Manure From a Below-Floor Concrete Manure Storage for 100 Cows With Round Trip Haul of 2.4 Kilometers

Trial	Pay Load M Tons	Average Percent Dry Matter	Machine Minutes Per M Ton Agitating*	Minutes Per M Ton Loading	Kilometers Per Hour	Minutes Per M Ton Spreading	Annual Labor Hours
L1A	4.06	13.80	9.82	0.41	10.06	0.56	172
L1B	4.72	13.80	9.77	0.45	13.97	0.82	132
L2A	3.29	10.89	10.91	0.67	16.66	0.69	193
L2B	4.41	10.89	10.99	0.56	19.09	1.08	162
L3A	4.75	14.18	9.26	0.54	13.82	0.23	110
L3B	7.85	14.18	9.30	0.41	15.40	0.25	69
Avg.	4.85	12.96	10.01	0.51	14.83	0.61	140

*zero labor assigned to this operation; agitators left unattended.

Manure dry matter payload is the single factor having the greatest effect on labor requirement. While Trial L2B had a travel rate 37% greater than Trial L1B, the annual labor requirement was 19% less for Trial L1B. This was caused primarily by the 36% manure dry matter payload advantage for Trial L1B. A larger spreader was used in Trial L3B and the average manure dry matter payload was 132% greater than Trial L2B. This resulted in an annual labor requirement advantage of 57% even with a travel rate disadvantage of 24% for Trial L3B.

Two Sahlstrom T 650 agitator pumps were used for agitating with one located at each end of the storage tank. Zero labor was assigned to the agitation process because the agitators were left unattended. This would not be a recommended practice if small children were present. Further, there is a risk of equipment damage should there be a malfunction.

Labor required for loading averaged 0.51 minutes per wet M. ton and labor for spreading averaged 0.61 minutes per wet M. ton.

Annual Fuel Requirement

Annual Fuel requirement for handling manure from storage as a liquid from 100 cows and with a round-trip haul of 2.4 kilometers averaged 5109 liters for the six trials (TABLE 24). Approximately 23% of the fuel (1173 liters) was used for hauling and spreading while 3936 liters or 77% was required for agitation and loading. Clearly, this method of storing and handling dairy manure is energy intensive. The shape of the storage tank and location of the agitator pumps (either end of the tank) in relation to location of manure input (center of tank) are not conducive to energy efficient agitation. Further, the Sahlstrom agitator/pump is less efficient than the newer submersible units. In view of this recognized energy inefficiency, these energy data were replaced by theoretical data in the economic analysis section of this report.

TABLE 24. Annual Fuel Requirement to Handle Liquid Manure From a Below-Floor Concrete Manure Storage for 100 Cows With Round Trip Haul of 2.4 Kilometers

Trial	Pay Load M Tons	Average Percent Dry Matter	Machine Minutes Per M Ton Agitating	M Tons Loaded Per Liter	Kilometers Per Liter	M-Ton Kilometers Per Liter Hauling & Spreading	Annual Fuel Liters
L1A	4.06	13.80	9.82	0.63	1.06	4.30	4,879
L1B	4.72	13.80	9.77	0.63	0.96	4.50	4,830
L2A	3.29	10.89	10.91	0.71	1.65	5.45	5,333
L2B	4.41	10.89	10.99	0.71	1.22	5.40	5,349
L3A	4.75	14.18	9.26	0.54	1.02	4.88	5,201
L3B	7.85	14.18	9.30	0.54	0.71	5.52	5,061
Avg.	4.85	12.96	10.01	0.63	1.10	5.01	5,109

Contrasted with labor requirements, fuel requirements for agitating, hauling and spreading were not significantly affected by manure dry matter payload. For example, Trial L3B had the largest manure dry matter payload, averaging 1.11 M. ton per load, yet fuel requirement was less than 1% lower than the average for all trials. Trial L2A had only 0.358 M ton manure dry matter payload and the fuel requirement was only 4.4% higher than the average for all trials. Fuel saved in hauling and spreading the 14.88% dry matter manure in Trial L3B was required to effectively agitate. In Trial L2A, the dry matter content was 10.89%, requiring considerably less fuel to agitate but more fuel to haul and spread -- a trade-off. However, in the interest of labor cost, tractor and spreader machine cost and reducing soil compaction, emphasis should be placed on hauling and spreading manure with the highest dry matter content practical.

Summaries of annual labor and fuel requirements to handle manure from storage as a liquid for each of the six trials are shown in Appendices F1 through F6. These summaries consider herd sizes of 50, 100 and 150 cows. Annual labor and fuel requirements are calculated for round-trip hauling distances of 0.8, 1.6, 2.4, 3.2, 4.0 and 4.8 kilometers.

Odor Control

Previous research and commercial farm experience have clearly established that odors are generated when liquid manure is agitated and/or pumped. An attempt was made to qualify the odor at the storage during agitation and in the field during spreading for Trials L1A and L1B. The odor evaluation form used is shown in Appendix A.

Two women and two men were selected for the odor evaluation panel. By design, none of the panel members were involved with the conduct of the research project or daily operation of the dairy research facilities. The evaluation was made on a June afternoon with the temperature at 29°C and no wind.

Odor evaluation at the storage was made in close proximity to the tractor-powered agitator pump at the South end of the storage tank. The panel members assessed the odor as follows: all four members reported a definite presence of odor, two described the odor as faintly offensive and two described the odor to be strongly offensive. Description of the odor included one yeasty, one ammonia, one rotten cabbage and one sour or fermented. Using the numerical rating on the evaluation form, the average composite rating of the presence of odor was 6.

Odor evaluation during spreading was made at a safe distance from the spreader, down wind and to the rear of the operation. The odor assessment by the panel was as follows: two members described the odor as very faint, one as a faint odor and one reported a definite odor. Description of the odor included two reporting very faintly offensive, one faintly offensive and one definitely offensive. The average composite numerical rating of the presence of odor was 3.5.

The panel members rated the odor less severe in the field compared to the storage location. One explanation is the intensity of the odor at the storage caused by continuous agitation and the opportunity for the panel members to make their assessment standing close to the agitation equipment.

Nutrient Conservation

Average nutrient loss through storage and unloading for Trials L1 and L2 was 10.3 percent nitrogen, 9.1 percent P_2O_5 and 7.9 percent K_2O (TABLE 25). The average dry matter of manure, including bedding, going into storage was 17.4 percent. The average dry matter of the liquid manure pumped out of storage for the two trials was 14.0 percent which is rather high for effective handling as a liquid. Considerable agitation was required to handle the high solids manure which probably contributed to the nutrient loss, particularly the nitrogen. Water was added equivalent to 24.4 percent of the manure by weight to reduce the solids from 17.4 to 14.0 percent. The addition of more water would have reduced agitation time but increased labor, energy and machine time for hauling and spreading.

SEMISOLID MANURE STORAGE AND SPREADING SYSTEM

Semisolid manure as defined for this project was as-produced manure including bedding materials but with no water added. The basic objective of this manure handling system design was to reduce the weight of manure by-product loaded out of storage, hauled and field spread per cow. The total weight of manure handled has a direct and significant impact on the annual cost for handling manure.

With daily hauling and spreading manure, one unit weight is hauled for each unit weight produced. With a liquid storage and handling system water is usually added to allow effective agitation and pumping. Typically, a 10 percent dry matter manure slurry is considered optimum. If the as-produced manure including bedding is at 15 percent dry matter, 50 M. tons of water must be added for each 100 M. tons of manure produced. Thus the total weight hauled to the field is increased by 50 percent over daily spreading. By storing manure in a roof covered storage and eliminating the addition of water, it was assumed that total weight of the manure by-product would be reduced through natural drying by possibly 10 percent.

Given the above assumption, the relative weights of manure by-product to haul would be 90, 100 and 150 M. tons for semisolid, daily spreading and liquid systems. Decreasing the weight of manure by-product to haul offers the potential of decreasing labor, energy and machine use requirements. Further, soil compaction should be reduced by reducing the weight of each load and/or the number of loads hauled over the field. The commercial scale side of this project placed significant emphasis on investigating the efficiency of semisolid manure storage and handling. Eight trials were conducted unloading the experimental roof-covered storage during the four year project.

TABLE 25. Manure Dry Matter Change and Nutrient Loss Through a Below Ground Concrete Liquid Manure Storage

Trial	Into Storage Out of Storage	M Tons of Manure	% D.M.	% Water Added	% Total N	M Tons Total N	% P_2O_5	M Tons P_2O_5	% K_2O	M Tons K_2O
L1	IN	73	17.4	25.9	0.59	0.434	0.25	0.184	0.40	0.294
	OUT	93	13.8		0.45	0.416	0.19	0.176	0.30	0.278
L3	IN	42	17.4	21.7	0.59	0.246	0.25	0.104	0.40	0.167
	OUT	51	14.2		0.38	0.193	0.17	0.086	0.29	0.147
		Total	Av.	w/Av.	Av.	Total	Av.	Total	Av.	Total
	IN	115	17.4		0.59	0.679	0.25	0.288	0.40	0.461
	OUT	143	14.0	24.4	0.42	0.610	0.18	0.262	0.30	0.425
NUTRIENT LOSS						0.069		0.026		0.036
PERCENT NUTRIENT LOSS						10.3%		9.1%		7.9%

Note: Results of Trial L2 were not included because laboratory assay results indicated signifcant error in sampling and/or laboratory procedure.

Annual Labor Requirement

Annual labor requirement for handling semisolid manure from 100 cows and with a round-trip haul of 2.4 kilometers averaged 99 hours for the eight trials (TABLE 26). Using this labor efficiency as a base, liquid storage and handling required 41 percent more labor and daily spreading required 199 percent more labor.

TABLE 26. Annual Labor Requirement to Handle Semisolid Manure From Roof-Covered Manure Storage For 100 Cows With Round Trip Haul of 2.4 Kilometers

Trial	Pay Load M Tons	Average Percent Dry Matter	Minutes Per M Ton Loading	Kilometers Per Hour	Minutes Per M Ton Spreading	Annual Labor Hours
SS1	3.98	18.6	0.47	11.67	0.97	137
SS2	5.59	20.2	0.94	13.57	0.44	90
SS3A	9.94	18.3	0.88	13.94	0.94	80
SS3B	5.56	18.3	0.95	14.31	0.35	87
SS4A	5.85	18.9	1.01	11.44	0.42	111
SS4B	9.09	18.9	0.95	11.91	0.35	82
SS5A	7.80	18.5	1.43	11.51	0.39	107
SS5B	6.85	18.5	1.09	11.83	0.39	102
SS6A	7.02	19.1	1.15	15.50	0.47	89
SS6B	6.49	19.1	1.05	12.99	0.40	96
SS7A	6.64	19.0	0.99	15.00	0.45	93
SS7B	6.64	19.0	1.08	18.80	0.52	89
SS8A	6.60	19.0	1.08	10.90	0.36	108
SS8B	6.49	19.0	1.17	10.67	0.44	115
Avg.	6.75	18.89	1.02	13.14	0.49	99

The annual labor equivalent for Trial SS1 was 137 hours. Five spreaders were used and the average pay load was 3.98 M. tons compared to 6.75 M. tons average for all trials. Four of the tractor drivers were inexperienced. Further, one man was assigned to the loader which resulted in very efficient loading (0.47 minutes per M. ton), but added to the overall labor requirement. Tractor operator inexperience was apparent when the drivers were positioning equipment at the storage and again during field spreading which required 0.97 minutes per M. ton compared to 0.49 minutes per M. ton for all SS trials.

For Trial SS2, one experienced farm tractor operator conducted the complete unloading. He removed the bulkhead sections as required, operated the steer-skid loader and the tractor spreader rig. Labor efficiency results of this trial equate to 90 man hours per year for a 100 cow herd based on hauling manure 2.4 kilometers round-trip. Loading time was 0.94 minutes per M. ton which is double the time required for Trial SS1. In Trial SS1 the loader operator was ready to dump a bucket of manure the moment the spreader was in position. Further, the spreader tractor operator left the loading station the moment the last bucket of manure was dumped. In Trial SS2 and all subsequent trials the spreader tractor operator also operated the loading tractor. Timing of the loading element started when the spreading tractor was shut off and stopped when the spreading tractor started. Therefore, the loading time element included the time required for the operator to dismount from the spreading tractor cab, walk to and enter the loading tractor cab and return to the spreading tractor.

Two experienced operators conducted Trials SS3 through SS8. In each of these trials one loader, two spreaders and hauling tractors were used. Time and energy data were recorded separately for each tractor/spreader rig to allow more evaluations of spreader types, sizes and kW requirements. These data were reported separately in A and B trials.

As was the case with liquid manure storage and handling, dry matter payload is one of the most important factors determining the total annual labor requirement. Trial SS3A averaged 1.82 M. tons dry matter payload compared to 1.28 M. tons dry matter payload for all trials (42 percent advantage). Annual labor requirement for Trial SS3A was 80 man hours compared to 99 man hours for all SS trials (19 percent advantage).

Similarly, Trial SS4B with an average dry matter payload advantage of 34 percent resulted in an annual labor requirement advantage of 17 percent compared to all SS trials.

Eight of the 14 SS Trials show an annual labor requirement of less than 100 man hours. Therefore, it is reasonable to conclude that with a semisolid manure management system, less than one man hour per cow per year is required to handle manure based on a 2.4 kilometer round trip haul.

Annual Fuel Requirement

Annual fuel requirement for handling semisolid manure from storage from 100 cows and with a round-trip haul of 2.4 kilometers averaged 921 liters for the eight SS trials (TABLE 27). Several different tractor/spreader rigs and one truck spreader were used (TABLE 20).

TABLE 27. Annual Fuel Requirement to Handle Semisolid Manure From Roof-covered Manure Storage for 100 Cows With Round Trip Haul of 2.4 Kilometers

Trial	Pay Load M Tons	Average Percent Dry Matter	M Tons Loaded Per Liter	Kilometers Per Liter	M Ton-Kilometer Per Liter Hauling & Spreading	Annual Fuel Liters
SS1	3.98	18.6	5.88	1.03	4.12	1,363
SS2	5.59	20.2	7.02	1.11	6.20	874
SS3A	9.94	18.3	2.81	.36	3.59	1,711
SS3B	5.56	18.3	7.59	1.19	6.64	825
SS4A	5.85	18.9	11.87	1.47	8.60	674
SS4B	9.09	18.9	11.87	.89	8.13	704
SS5A	7.80	18.5	19.32	.94	7.31	715
SS5B	6.85	18.5	19.32	1.00	6.87	753
SS6A	7.02	19.1	8.95	.71	5.03	1,071
SS6B	6.49	19.1	8.95	1.00	6.50	874
SS7A	6.64	19.0	6.99	1.20	8.00	855
SS7B	6.64	19.0	6.99	1.03	6.82	958
SS8A	6.60	19.0	15.94	1.05	6.91	768
SS8B	6.49	19.0	15.94	1.11	7.19	746
Avg.	6.75	18.89	10.67	1.01	6.56	921

In Trial SS1, the average dry matter payload was 42 percent lower than the average for all SS trials. This was caused by the use of small spreaders requiring more trips to the field, resulting in a 48 percent increase in annual fuel requirement over the average for all SS trials.

Trial SS3A was atypical in that a 10.39 cubic meter tandem axle fertilizer/lime spreader truck was used to haul and spread manure and a payloader with a 2.68 m^3 bucket was used to load manure. Objective was to determine how effective and efficient this unit was for spreading manure. The unit functioned well except for the time required to spread, which was 89 percent more than the average for all SS trials. This was caused by the small discharge opening restricting the flow of manure but necessary to control the flow of fertilizer. M. ton-kilometers per liter of fuel for hauling and spreading was 45 percent lower than the average for all SS trials. The payloader required 380 percent more fuel than the average of all steer-skid loaders used in the other SS trials. With the energy inefficiency for loading and spreading, Trial SS 3A required 86 percent more fuel than the average for all SS trials.

Summaries of annual labor and fuel requirements to handle semisolid manure from storage for each of the trials are shown in Appendices G1 through G14. These summaries consider herd sizes of 50, 100 and 150 cows. Annual labor and fuel requirements are calculated for round-trip hauling distances of 0.8, 1.6, 2.4, 3.2, 4.0 and 4.8 kilometers.

Odor Control

The roof-covered semisolid manure storage was loaded from the bottom with a solid piston hydraulic ram. Once the manure reached the perimeter of the storage a crust layer would form on top providing a "seal" to the storage. During the winter the crust layer would freeze to a depth of 30.48 cm to 35.56 cm. The crust layer essentially eliminated odors at the storage during the storage period.

During unloading and spreading of the semisolid manure for Trials SS1 and SS8, an odor evaluation was made using the odor evaluation form shown in Appendix A. Three employees at the Research Center, not involved with the research project or daily operation of the dairy research facilities, were selected for the Trial SS1 panel. The panel for Trial SS8 had five members including a secretary from the Agway general office, a neighbor to the Research Center and three Research Center employees.

Trial SS1 was conducted on a May day with the temperature at 18°C. At 10:00 AM and 3:00 PM odor evaluation was made at the storage during the unloading process. At 10:30 AM and 4:00 PM odor evaluation was made in the field following the spreader. The panel members assessed the odor as follows: AM reading at storage, all 3 members reported a very faint odor, one described the odor as no offensive odor and two as very faint offensive odor; PM reading at storage, all three members reported a very faint odor, two describing the odor as very faint offensive odor and one as faint offensive odor. Using the numerical rating on the evaluation form, the average composite rating of the presence of odor at the storage was 2.

Odor evaluation during spreading was made downwind and to the rear of the operation. The odor asessment by the panel was: AM reading in field, one member reported a definite odor, two reported very faint odor, all three described the odor as very faint offensive odor; PM reading in field, one reported faint odor, two reported very faint odor, one described the odor as faint offensive odor and two as very faint offensive odor. The average composite numerical rating of the presence of odor in the field was 3.

Trial SS8 was conducted on a late October day with the temperature at 7°C and a 19 km per hour wind from the west. A 3:00 PM odor evaluation was made at the storage and a 3:30 PM evaluatin made in the field downwind from the spreading operation. A five member panel assessed the odor as follows: at storage, three members reported a very faint odor, two reported definite odor, one described the odor as no offensive odor, two as very faint offensive odor and two as faint offensive odor. The average composite rating of the presence of odor at the storage was 3.6.

The panel assessed the presence of odor during the field spreading as follows: two reported faint odor, one reported definite odor, two reported strong odor, two described the odor as very faint offensive odor, one as faint offensive odor and two as strong offensive odor. The average composite rating of the presence of odor during spreading for Trial SS8 was 6.

The presence of odor was more pronounced during Trial SS8 than for Trial SS1. Two factors probably contribute to the significant difference. First, the make-up of the two panels and second, the 19 km per hour wind during Trial SS8. Clearly, this signals the desirability of spreading manure on a relatively quiet day. During both trials the presence of odor was judged to be greater during spreading in the field compared to the loading operation at the storage. Loading semisolid manure with a bucket loader disturbs the manure only slightly, thus minimizing odor release. Field spreading for uniform coverage breaks up the manure thus increasing the release of odor. Early incorporation of the manure into the soil by harrow or plow will control the duration of odor release.

The presence of odor at the storage during the loading process was considerably greater for Trials L1A and L1B (liquid manure handling) compared to Trials SS1 and SS8 (semisolid manure handling). Basic cause of the increased odor at the storage is the agitation required to handle the manure as a liquid. There was no significant difference in the presence of odor during field spreading between liquid and semisolid manure handling.

Nutrient Conservation

Average nutrient loss through storage and unloading for Trials SS1 through SS8 was 4.6 percent nitrogen, 6.4 percent P_2O_5 and 6.7 percent K_2O (TABLE 28). The average dry matter of the as-produced manure, including bedding, going into storage was 17.3 percent. The average dry matter of

TABLE 28. Manure Dry Matter Change and Nutrient Loss Through a Roof-covered Above Ground Concrete Semisolid Manure Storage

Trial	Into Storage Out of Storage	M Tons of Manure	% D.M.	% Evaporation	% Total N	M Tons Total N	% P_2O_5	M Tons P_2O_5	% K_2O	M Tons K_2O
SS1	IN	643	15.9		0.57	3.67	0.34	2.19	0.31	2.00
	OUT	550	18.6	14.5	0.51	3.36	0.26	1.43	0.35	1.92
SS2	IN	423	17.4		0.57	2.41	0.25	1.06	0.34	1.43
	OUT	364	20.2	13.9	0.62	2.26	0.29	1.05	0.34	1.23
SS3	IN	387	17.4		0.64	2.48	0.26	1.01	0.38	1.47
	OUT	368	18.3	4.9	0.65	2.39	0.28	1.03	0.39	1.43
SS4	IN	512	16.4		0.54	2.77	0.19	0.97	0.35	1.79
	OUT	444	18.9	13.3	0.57	2.53	0.23	1.02	0.36	1.60
SS5	IN	412	17.3		0.62	2.55	0.22	0.91	0.32	1.32
	OUT	386	18.5	6.4	0.63	2.43	0.23	0.89	0.29	1.12
SS6	IN	443	17.3		0.57	2.52	0.27	1.20	0.43	1.91
	OUT	401	19.1	9.4	0.59	2.37	0.29	1.16	0.40	1.61
SS7	IN	400	18.7		0.60	2.40	0.29	1.16	0.34	1.36
	OUT	394	19.0	1.6	0.61	2.40	0.29	1.14	0.32	1.26
SS8	IN	474	18.4		0.59	2.80	0.21	1.00	0.40	1.90
	OUT	459	19.0	3.3	0.61	2.80	0.25	1.15	0.46	2.11
		TOTAL	AV.	W/AV.	AV.	TOTAL	AV.	TOTAL	AV.	TOTAL
	IN	3,694	17.3		0.588	21.6	0.25	9.49	0.40	13.16
	OUT	3,365	19.0	8.9	0.611	20.6	0.27	8.88	0.36	12.28
NUTRIENT LOSS						1.0		0.61		0.88
PERCENT NUTRIENT LOSS						4.6%		6.4%		6.7%

manure loaded out of storage was 19.0 percent. For every 100 M. tons of manure placed in storage, 91.1 M. tons were removed, which indicates an evaporation of 8.9 percent. An evaporation of 10 percent was projected as previously stated.

The P_2O_5 and K_2O nutrient loss was only slightly less than with the liquid manure storage and handling system. The nitrogen loss (4.6 percent) was less than half that experienced with the liquid system. It is judged that agitating manure to create a pumpable slurry in a liquid manure storage is the primary cause of nitrogen loss through volatilization of ammonia gas. Bucket loading of semisolid manure does not create the same conditions.

SUMMARY OF ANNUAL LABOR AND FUEL REQUIREMENTS FOR THREE MANURE MANAGEMENT SYSTEMS

Rising labor costs during the 1950s and 1960s concerned commercial dairymen and spiraling energy costs during the 1970s became a major concern. Results of this research show that labor required to handle dairy manure is significantly less with either a liquid or semisolid manure storage system compared to daily spreading (TABLE 29). Further, there is equal potential for reducing fuel costs with the semisolid manure storage system compared to daily spreading.

TABLE 29. Summary of Annual Labor and Fuel Requirements For Three Manure Management Systems and Three Herd Sizes*

Type of System	Labor Hours	Fuel Liters
1. daily spreading of manure from barn		
50 cows	211	1,306
100 cows	296	2,613
150 cows	381	3,918
Composite Total	888	7,837
2. handling liquid manure through a below-ground concrete storage		
50 cows	70	2,551
100 cows	140	5,109
150 cows	210	7,661
Composite Total	420	15,321
3. handling semisolid manure through a roof-covered storage		
50 cows	49	462
100 cows	99	921
150 cows	148	1,382
Composite Total	296	2,765

*Based on a round-trip hauling distance of 2.4 km.

TABLE 30. Annual Operating Costs For Daily Spreading Manure Management Systems

Description of System

1. chain gutter cleaner to collect and transfer manure to loading area
2. roof-covered, concrete floor manure loading area at end of barn
3. box type spreader with tailgate or tank type spreader sized for one load per day
4. average distance to haul manure is 2.4 kilometers (round trip)

Fixed Costs For Equipment and Facilities

Equipment & Facilities Installed	Economic Life Years	Investment Cost Number of Cows			Av. Prin. & Interest* Number of Cows			Insur. & Taxes % of Invest.	Re-pairs % of Invest.	Annual Cost Number of Cows		
		50	100	150	50	100	150			50	100	150
1. gutter cleaner	10	$5,832	$ 8,082	$10,455	$1,087	$1,506	$1,948	1.5	5	$1,466	$2,031	$2,628
2. roof-covered loading area	20	7,500	7,500	7,500	992	992	992	1.5	2	1,255	1,255	1,255
3. box spreader w/tailgate	4	7,100	10,450	12,852	2,329	3,427	4,215	1.5	10	3,146	4,629	5,693
TOTAL ANNUAL FIXED COSTS										$5,867	$7,915	$9,576

*14% interest on equipment and 12% interest on structures

(continued)

TABLE 30 (continued)

Annual Labor, Electrical and Tractor Use Cost

OPERATION				Herd Size 50	100	150
1. annual labor cost for loading, hauling and spreading manure at $5/hour						
50 cows	211 hours			$ 1,055		
100 cows	296 hours				$ 1,480	
150 cows	381 hours					$ 1,905
2. annual electrical cost to operate gutter cleaner @ $.06/kWH						
50 cows	128 hours	1.49 kW motor	1.7 kW draw	13		
100 cows	233 hours	2.24 kW motor	2.6 kW draw		36	
150 cows	339 hours	3.73 kW motor	4.3 kW draw			87
3. annual tractor use cost to haul and spread manure @ $.221/kW hour						
50 cows	279 hours	52.22 kW tractor		3,222		
100 cows	432 hours	74.60 kW tractor			7,128	
150 cows	585 hours	93.25 kW tractor				12,066
4. annual labor to lubricate and service gutter cleaner and spreader @ $5/hour						
50 cows	78 hours			390		
100 cows	91 hours				455	
150 cows	104 hours					520
				$ 4,680	$9,099	$14,578
TOTAL ANNUAL COSTS						
1. Annual fixed costs				$ 5,867	$ 7,915	$ 9,576
2. Annual labor, electrical and tractor use cost				4,680	9,099	14,578
TOTAL				$10,547	$17,014	$24,154
PER COW COST				$ 211	$ 170	$ 161

TABLE 31. Annual Operating Costs For Handling Liquid Manure From Above Ground Tank Type Storage

Description of System

1. chain gutter cleaner to collect and transfer manure to reception pit at end of barn
2. cutter pump (14.92 kW) to homogenize and transfer manure under ground to storage
3. glass fused to steel storage with 6 months storage capacity
4. 8.50 cubic meter tank type manure spreader
5. average distance to haul manure is 2.4 kilometers (round trip)

Fixed Costs For Equipment and Facilities

Equipment and Facilities Installed	Economic Life Years	Investment Cost Number of Cows			Average Prin. & Interest* Number of Cows			Insur. & Taxes % of Invest.	Repairs % of Invest.	Annual Cost Number of Cows		
		50	100	150	50	100	150			50	100	150
1. gutter cleaner	10	$ 5,754	$ 8,004	$10,377	$1,072	$1,492	$1,934	1.5	5.0	$ 1,446	$ 2,012	$ 2,609
2. reception pit	20	2,400	3,400	4,400	317	450	582	1.5	2.0	401	569	736
3. cutter pump	10	9,550	9,550	9,550	1,780	1,780	1,780	1.5	7.5	2,640	2,640	2,640
4. 30.48 m of 15.2 cm pipe	20	650	650	650	86	86	86	1.5	2.0	109	109	109
5. tank storage	20	26,800	43,000	61,900	3,544	5,686	8,186	1.5	2.0	4,482	7,191	10,353
6. pump out accessories	10	1,000	1,000	1,000	186	186	186	1.5	2.0	221	221	221
7. 8.50 m^3 spreader	8	12,852	12,852	12,852	2,680	2,680	2,680	1.5	5.0	3,515	3,515	3,515
TOTAL ANNUAL FIXED COSTS										$12,814	$16,257	$20,183

*14% interest on equipment and 12% interest on structures

(continued)

TABLE 31 (continued)

Annual Labor, Electrical and Tractor Use Cost

OPERATION				Herd Size 50	100	150
1. annual electrical cost to operate gutter cleaner @ $.06/kWH						
50 cows	128 hours	1.49 kW motor	1.7 kW draw	$ 13		
100 cows	233 hours	2.24 kW motor	2.6 kW draw		$ 36	
150 cows	339 hours	3.73 kW motor	4.3 kW draw			$ 87
2. annual electrical cost to operate 14.92 kW cutter pump @ $.06/kWH in reception pit						
50 cows	166 hours			133		
100 cows	333 hours				268	
150 cows	499 hours					401
3. annual labor cost @ $5/hour to operate cutter pump in reception pit						
50 cows	59 hours			295		
100 cows	59 hours				295	
150 cows	59 hours					295
4. annual tractor use cost @ $2.21/kW hour to haul and spread manure						
50 cows	54 hours			1,114		
100 cows	108 hours				2,228	
150 cows	162 hours					3,342
5. annual labor cost @ $5/hour to agitate, load, haul and spread manure						
50 cows	59 hours			295		
100 cows	116 hours				580	
150 cows	173 hours					865
6. annual electrical cost to operate 14.92 kW cutter pump @ $.06/kWH in storage						
50 cows	38 hours			31		
100 cows	60 hours				48	
150 cows	82 hours					66
7. annual labor cost @ $5/hour to lubricate & service gutter cleaner, cutter pump and spreader						
50 cows	50 hours			250		
100 cows	67 hours				335	
150 cows	84 hours					420
				$ 2,131	$ 3,790	$ 5,476
TOTAL ANNUAL COSTS						
1. Annual fixed costs				$12,814	$16,257	$20,183
2. Annual labor, electrical and tractor use costs				2,131	3,790	5,476
			Total	$14,945	$20,047	$25,659
PER COW COST				$ 299	$ 200	$ 171

TABLE 32. Annual Operating Costs For Handling Semisolid Manure From Roof-Covered Manure Storage

Description of System

1. chain gutter cleaner to collect and transfer manure to end of barn
2. hydraulic manure ram (3.73 kW) to transfer manure under ground to storage
3. roof-covered manure storage with 6 months storage capacity
4. 8.50 cubic meter tank type manure spreader
5. average distance to haul manure is 2.4 kilometers (round trip)

Fixed Costs For Equipment and Facilities

Equipment and Facilities Installed	Economic Life Years	Investment Cost Number of Cows			Average Prin. & Interest* Number of Cows			Insur. & Taxes	Repairs	Annual Cost Number of Cows		
		50	100	150	50	100	150	% of Invest.	% of Invest.	50	100	150
1. gutter cleaner	10	$ 5,754	$ 8,004	$10,377	$1,072	$1,492	$1,934	1.5	5.0	$ 1,446	$ 2,012	$ 2,609
2. manure ram	10	6,900	6,900	6,900	1,286	1,286	1,286	1.5	7.5	1,907	1,907	1,907
3. 30.48 m of 30.4 cm pipe	20	1,400	1,400	1,400	185	185	185	1.5	2.0	234	234	234
4. ram room	20	2,000	2,000	2,000	264	264	264	1.5	2.0	334	334	334
5. roof-covered storage	20	17,350	24,400	36,850	2,294	3,227	4,873	1.5	2.0	2,901	4,081	6,163
6. 8.50 m^3 spreader	8	12,852	12,852	12,852	2,680	2,680	2,680	1.5	5.0	3,515	3,515	3,515
TOTAL ANNUAL FIXED COSTS										$10,337	$12,083	$14,762

*14% interest on equipment and 12% interest on structures

(continued)

TABLE 32. (continued)

Annual Labor, Electrical and Tractor Use Cost

OPERATION				Herd Size		
				50	100	150
1. annual electrical cost to operate gutter cleaner @ $.06/kWH						
50 cows	256 hours	1.49 kW motor	1.7 kW draw	$ 26		
100 cows	466 hours	2.24 kW motor	2.6 kW draw		$ 72	
150 cows	678 hours	3.73 kW motor	4.3 kW draw			$ 174
2. annual electrical cost to operate manure ram (3.73 kW motor)						
50 cows	275 hours			71		
100 cows	550 hours				142	
150 cows	825 hours					213
3. annual labor cost for loading, hauling and spreading manure @ $5/hour						
50 cows	42 hours			210		
100 cows	84 hours				420	
150 cows	126 hours					630
4. annual tractor use cost to load manure @ $.221/kW hour						
50 cows	16 hours	33.57 kW tractor		119		
100 cows	31 hours	33.57 kW tractor			230	
150 cows	46 hours	33.57 kW tractor				342
5. annual tractor use cost to haul and spread manure @ $.221/kW hour						
50 cows	42 hours	93.25 kW tractor		866		
100 cows	84 hours	93.25 kW tractor			1,733	
150 cows	126 hours	93.25 kW tractor				2,599
6. annual labor cost to lubricate and service gutter cleaner, ram and spreader @ $5/hour						
50 cows	72 hours			360		
100 cows	102 hours				510	
150 cows	132 hours					660
				$ 1,652	$ 3,107	$ 4,618
TOTAL ANNUAL COSTS						
1. Annual fixed costs				$10,337	$12,083	$14,762
2. Annual labor, electrical and tractor use cost				1,652	3,107	4,618
TOTAL				$11,989	$15,190	$19,380
PER COW COST				$ 240	$ 152	$ 129

Referring to Table 29, the composite of labor required to daily spread manure from a 50 cow herd, 100 cow herd and 150 cow herd is 888 hours. Using this as reference base, the liquid manure storage system reduces labor 53 percent and the semisolid storage system reduces labor 67 percent. The composite of fuel required to daily spread manure from the three herds is 7,837 liters. Again using this as reference base, the liquid manure storage system increases fuel used by 95 percent while the semisolid storage system reduces fuel used by 65 percent. As previously pointed out, the liquid manure storage tank used with this project was not conducive to efficient agitation and caused increased energy requirements.

ANNUAL COSTS FOR THREE MANURE MANAGEMENT SYSTEMS

Pollution control, nutrient conservation and annual costs are the primary criteria for selecting a manure management system. This section focuses on analyzing annual costs of three manure management systems based on actual performance data generated through the conduct of this project. Total annual operating costs for a daily spreading system are shown in Table 30, for liquid manure storage and handling in Table 31 and for semisolid manure storage and handling in Table 32.

Annual costs are partitioned between fixed costs for equipment and facilities and operational costs for labor, electrical and tractor use cost. Generally as fixed costs increase operational costs decrease, which underscores the importance of analyzing total annual costs when comparing systems. While tax implications have a significant effect on annual costs, favoring systems with higher fixed costs, no attempt was made to factor them in. The actual effect of investment tax and depreciation tax credits on annual operating costs will vary widely from farm to farm depending on the overall profitability of the farm enterprise.

An economic life was established for each piece of equipment and structure based on experience at the Agway Farm Research Center and generally accepted practice. The depreciation term and/or loan term was considered to be the same as the economic life. Residual value of all equipment and structures was assumed to be zero.

Investment costs are fall 1982 costs of equipment and structures delivered and installed in central New York. Appendix H shows the detail of equipment and structure costs including all labor and accessories for installation. Interest rates of 14 percent and 12 percent were established for equipment and structures respectively. Annual level payments for principal and interest were calculated using Comprehensive Mortgage Payment Tables published by Financial Publishing Company, Boston, Massachusetts.

Gutter cleaners, pumps, rams, spreaders and storages were totally assigned to the respective manure management system investment costs. Tractors were not treated as part of the system investment because only a fraction of their annual operating hours are required for manure handling. An hourly use cost, including fuel, was determined for tractors required for each system (TABLE 33). This cost remains constant when calculated on a kW hour basis. A cost of $0.221 per kW hour was used for all systems.

TABLE 33. Tractor Use Cost

PTO kW	Fuel	Ownership Cost Per Hour*	Fuel Cost Per Hour**	Total Cost Per Hour	Cost Per kW Hour
37.30	gasoline	$ 5.40	$2.34	$ 7.74	20.8¢
48.49	gasoline	8.25	3.05	11.30	23.3¢
63.41	diesel	10.80	3.19	13.99	22.1¢
78.33	diesel	13.30	3.94	17.24	22.0¢
96.98	diesel	16.50	4.88	21.38	22.0¢

*Source: Donnel Hunt, PhD, Department of Agricultural Engineering, University of Illinois, Urbana, Illinois.

**Based on 1.577 kW hours/liter gasoline for 37.30 and 48.49 kW tractors and 1.971 kW hours/liter diesel for larger tractors. Consider tractor operating at 30 percent of rated PTO kW (project data ranged 21 to 36 percent) and fuel costing $0.33 per liter.

Annual cost for insurance and taxes was taken at 1.5 percent of the original investment. Annual cost for repairs was taken as a percent of original investment and varied from 2 to 10 percent based on generally accepted practice.

A labor rate of $5.00 per hour was established for all labor functions. Electrical costs were calculated for each motor using recorded kilowatt draw and annual hours used. An electrical rate of $.06 per kilowatt hour was applied. Appendix I shows the detail of all labor, electrical and tractor use calculations.

SUMMARY OF TOTAL ANNUAL COSTS FOR THREE MANURE MANAGEMENT SYSTEMS

Table 34 compares in summary the fixed, operating, total and per cow costs of handling dairy manure with three different manure management systems. Cost data are presented for three herd sizes to show the effect of herd size on per cow cost of handling manure.

The fixed costs are based on prevailing prices for equipment and structures in central New York in the fall of 1982. Operating costs for the daily manure spreading system and the semisolid manure storage system are based on performance factors documented during the conduct of this study. As previously stated, the liquid manure handling system used in this study was energy inefficient. Therefore, in analyzing costs for liquid manure handling, the decision was made to project operating costs based on an above-ground tub silo liquid storage and a cutter pump for loading and unloading the storage.

TABLE 34. Summary of Total Annual Costs for Three Manure Management Systems and Three Herd Sizes

Type of System	Annual Costs Fixed	Operating	Total	Per Cow
1. daily spreading of manure from barn				
50 cows	$ 5,867	$ 4,680	$10,547	$211
100 cows	7,915	9,099	17,014	170
150 cows	9,576	14,578	24,154	161
2. handling liquid manure through an above-ground tub silo storage				
50 cows	12,814	2,131	14,945	299
100 cows	16,257	3,790	20,047	200
150 cows	20,183	5,476	25,659	171
3. handling semisolid manure through a roof-covered storage				
50 cows	10,337	1,652	11,989	240
100 cows	12,083	3,107	15,190	152
150 cows	14,762	4,618	19,380	129

Referring to Table 34 and focusing on the 100 cow herd size, fixed costs increase 105 percent for liquid manure storage and handling and 53 percent for semisolid manure storage and handling over the daily spreading system. Conversely, operating costs decrease 58 percent for liquid manure storage and handling and 66 percent for semisolid manure storage and handling compared to daily spreading manure.

Looking at total annual costs (no credit for fertilizer nutrient recovery), semisolid manure storage and handling is the least cost system at the 150 cow level, followed by daily spreading and liquid manure storage and handling. At the 100 cow level, semisolid is still the least cost system, but at the 50 cow level daily spreading becomes the least cost system.

POTENTIAL ANNUAL IMPROVEMENT TO FARM ENTERPRISE PROFIT WITH A MANURE STORAGE SYSTEM

Calculating annual costs of manure handling systems as presented in Tables 30 through 34 can be done with a high degree of reliability if performance data and investment data are at hand. Projecting the dollar return through nutrient recovery as crop fertilizer is far more subjective. Variations in existing soil fertility, soil type, rate of manure application, crops grown and climatic conditions are some of the factors which will influence actual dollar return through fertilizer nutrient recovery.

For this discussion, nutrient recovery from a daily spreading system will be used as a reference base and, therefore, can be established at any reasonable level. The generally accepted analysis of daily spread dairy manure is 2.5-1.5-3. Assume that the unit values of the nutrients are: N @ \$.66 per kilogram, P_2O_5 @ \$.53 per kilogram, and K_2O @ \$.33 per kilogram. Cows in this study produced manure, including bedding, at the rate of 54.43 kilograms per cow per day. Annual per cow value of nutrients would be \$68.25.

This study measured the relative effectiveness of three manure management systems in recovering fertilizer nutrients through actual crop yield. These data are reported in Table 15. The stored liquid manure spring applied shows a 19 percent improvement over daily spread and the stored semisolid manure spring applied shows a 29 percent advantage over daily spread.

Applying these relative efficiency percentages to the \$68.25 value of nutrients from daily spreading shows a nutrient recovery value of \$81 per cow per year for a liquid manure storage system and \$88 per cow per year for the semisolid manure storage system.

These fertilizer nutrient recovery values are reported in Table 35 and subtracted from the annual operating costs to arrive at the net cost per cow per year for each system. Table 35 shows that a liquid manure storage system will improve the profit potential on a 150 cow or larger dairy and a semisolid manure storage system will improve the profit potential on a 60 cow or larger dairy compared to daily spreading.

TABLE 35. Potential Annual Improvement to Farm Enterprise Profit With a Manure Storage System

	Per Cow			
Type of System	Total Fixed & Operating Costs	Fertilizer Nutrient Recovery	Net Costs	Profit Gain or (Loss) Over Daily Spreading
Daily spreading of manure from barn				
50 cows	$ 211	$ 68	$ 143	--
100 cows	170	68	102	--
150 cows	161	68	93	--
Handling liquid manure through 6 months tub silo storage				
50 cows	299	81	218	(75)
100 cows	200	81	119	(17)
150 cows	171	81	90	3
Handling semisolid manure through 6 months roof-covered storage				
50 cows	240	88	152	(9)
100 cows	152	88	64	38
150 cows	129	88	41	52

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APPENDIX A

ODOR EVALUATION FORM

Presence of Odor

_____ no odor

_____ very faint odor

_____ faint odor

_____ definite odor

_____ strong odor

_____ very strong odor

Offensiveness of Odor

_____ no offensive odor

_____ very faint offensive odor

_____ faint offensive odor

_____ definite offensive odor

_____ strong offensive odor

_____ very strong offensive odor

Description of Odor

_____ moldy or musty

_____ fish or fish-like

_____ stagnant water

_____ sulfide or rotten egg

_____ petroleum or oily

_____ rotten cabbage or mercaptan

_____ earthy

_____ yeast

_____ ammonia

_____ grain or feed

_____ sour or fermented

Temperature: ____________________

Relative humidity: ______________

Wind velocity: __________________

Wind direction: _________________

Name: __________________________

Date: __________________________

Time: __________________________

Location: _______________________

APPENDIX B

Daily Spreading of Manure -- Work Sheets For Calculating Annual Labor and Fuel Requirements

TRIAL # DS1

A. Barn Data

1. dates of trial period: FEB. 25 - MARCH 5
2. number of days in trial: 5
3. total cow days in daily spread manure trial: 296
4. average kilograms of milk produced per cow day: ____
5. bedding used:
   a. type SAWDUST
   b. kilograms 1339
   c. kilograms per cow day (A5b ÷ A3) 4.52

B. General Data

1. total manure & bedding spread 18,807 kilograms, 18.81 M. tons
2. average kilograms of manure and bedding per cow day hauled and spread (B1 ÷ A3) = 63.5
3. average number of cows in time trial (A3 ÷ A2) = 59.2
4. total loads of manure hauled (from Form #135): 5
5. average weight per load (B1 ÷ B4) = 3761 kilograms, 3.76 M. tons
6. total kilometers traveled by spreading tractor: 7.98
7. average kilometers traveled per round trip (6 ÷ 4) = 1.59
8. manure production/cow/year $\left(\frac{B1 \times 365}{A3}\right) = \frac{18.81 \times 365}{296} = 23.19$ M. tons

(continued)

TRIAL #DS1

C. Labor Input Data

1. Incremental times (minutes) from Form #135

Function	Trial Total	Av. Per Day	Per Cow
	minutes		
a. positioning spreader under barn cleaner	31.54	6.31	
b. loading spreader*	75.26	15.05	** 0.25
c. hauling	52.47		
d. spreading	17.03	3.41	0.0575
e. weighing	8.40		

*Use 50% of total time required for barn cleaner to load spreader as manure handling labor input. Assume other 50% of labor directed to other chores.

**Calculated on basis of 60 cow barn.

D. Fuel Input Data

2. fuel input (liters from Form #131)

	Gasoline	Diesel	Total
a. tractor on spreader		17.41	17.41

3. M. ton-kilometers per liter $\left(\frac{B5 \times B6}{D2a}\right) = \frac{3.76 \times 7.98}{17.41} =$ 1.72

4. annual fuel per km per cow $\left(\frac{B8}{D3}\right) = \frac{23.19}{1.72} =$ 13.45 L

E. Equipment Used

1. tractors: manufacturer, model, kW, and fuel type
   a. OLIVER, MODEL 1850, 69.4 kW, DIESEL
   b.

2. spreaders: m^3, manufacturer, model
   a. 5.49 m^3, INTERNATIONAL HARVESTER, MODEL 580
   b.

Prepared by: R. O. Martin Date: 9/29/82 Checked by: Alice Britt

(continued)

APPENDIX B (continued)

TRIAL #DS1

Calculation of Time Required to Perform Individual Function

Position spreader under barn cleaner

6.31 minutes per day (constant)

38 hours per year (constant for all herd sizes and hauling distances)

Loading spreader with barn cleaner

0.25 minutes per cow day

herd size	minutes/day	hours/year
50	12.5	76
100	25.0	152
150	37.5	228

Hauling

average hauling rate: $\frac{52.47 \text{ mins.}}{7.98 \text{ km.}}$ = 6.57 mins./km

hauling distance		minutes per kilometer		minutes per day	hours/year
0.8	x	6.57	=	5.26	32
1.6	x	6.57	=	10.51	64
2.4	x	6.57	=	15.77	97

Spreading

0.0575 minutes per cow per day

herd size	minutes/day	hours/year
50	2.88	17
100	5.75	35
150	8.63	52

Prepared by: R. D. Martin Date: 9/29/82 Checked by: Alice Britt

(continued)

APPENDIX B (continued)

TRIAL # DS1

Calculation of Annual Labor Requirement for Various Size Herds And Hauling Distances

Herd Size			round-trip hauling distance (kilometers)		
			0.8	1.6	2.4
			hours		
	position spreader		38	38	38
	loading spreader		76	76	76
	total loading		114	114	114
	hauling		32	64	97
	spreading		17	17	17
50		TOTAL	163	195	228
	position spreader		38	38	38
	loading spreader		152	152	152
	total loading		190	190	190
	hauling		32	64	97
	spreading		35	35	35
100		TOTAL	257	289	322
	position spreader		38	38	38
	loading spreader		228	228	228
	total loading		266	266	266
	hauling		32	64	97
	spreading		52	52	52
150		TOTAL	350	382	415

Prepared by: R. O. Martin Date: 9/29/82 Checked by: Alice Britt

(continued)

TRIAL # DS1

Calculation of Annual Fuel Requirement for Various Size Herds And Hauling Distances

average number of cows in this trial (B3) = 59.2

average round-trip haul for this trial (B7) = 1.59 kilometers

annual fuel required per kilometer per cow (D4) = 13.45 liters

Annual Fuel Requirement

Herd Size	round-trip hauling distance (kilometers) 0.8	1.6	2.4
50	541	1083	1624
100	1083	2165	3248
150	1624	3248	4872

Prepared by: R. O. Martin Date: 9/29/82 Checked by: Alice Britt

(continued)

TRIAL # DS1

Performance Data

		herd size		
		50	100	150
1.	minutes loading per M. ton of manure $\frac{((C1b \times \text{cow numbers}) + C1a) \times 365}{B8 \times \text{cow numbers}}$	5.92	4.93	4.60
2.	average km per hour $\left(\frac{B6 \times 60}{C1c}\right) =$	9.12	9.12	9.12
3.	minutes spreading per M. ton (C1d ÷ B1) =	0.90	0.90	0.90
4.	M ton-kilometers per liter $\left(\frac{B5 \times B6}{D2a}\right) =$	1.73	1.73	1.73
5.	kilometers/liter (B6 ÷ D2a) =	0.46	0.46	0.46

Prepared by: R.D. Martin Date: 9/29/82 Checked by: Alice Britt

APPENDIX C

Liquid Storage and Handling of Manure -- Work Sheets for Calculating Annual Labor and Fuel Requirements

TRIAL #LIA

A. Barn and Liquid Manure Storage Tank Data

1. confinement stall barn with 60 stalls
2. concrete liquid manure storage tank located at west end of barn below grade
3. interior dimensions of tank:

length	15.39 m
width	3.15 m
depth	2.44 m

4. manure delivered to storage tank by Starline barn cleaner

B. Liquid Manure Storage Unloading Data

1. date of unloading JUNE 24
2. depth of manure in tank

	south end	north end	average depth
a. start of trial	111.00	111.00	110.00 cm
b. end of trial	24.51	24.55	24.53 cm
c. total depth removed			85.47 cm
d. volume of manure removed			

15.39 m x 3.15 m x B2c = 41.43 m^3

3. total kilograms of manure weighed out of storage 40,522 kilograms, 40.52 M. tons
4. average density of manure (B3 ÷ B2d) = 978 kg/m^3
5. total loads of manure hauled (from Form #135) 10 loads
6. average weight per load (B3 ÷ B5) = 4,052 kilograms, 4.05 M. tons
7. total kilometers traveled by spreading tractors 33.33 kilometers
8. average kilometers travel per spreader, round-trip (B7 ÷ B5) = 3.33 kilometers/trip
9. average percent dry matter from each load 13.8 %
10. total dry matter (B3 x B9) = 5,592 kilograms
11. cow days in trial (B10 ÷ 8.62 kg/cow day*) = 649 cow days
12. manure hauled per cow day
    a. cubic meters (B2d ÷ B11) = 0.0638
    b. kilograms (B3 ÷ B11) = 62.44

*from semisolid manure handling trials

(continued)

TRIAL # L1A

C. Labor and fuel data

1. incremental times (minutes) from Form #135

a. loading 16.530 mins.
b. hauling 198.744 mins.
c. spreading 22.783 mins.
d. weighing 16.450 mins.
e. idling 10.983 mins.

2. fuel input (liters from Form #131)

	gasoline	diesel	total
a. agitator/pump tractors		63.97	63.97
b. tractors on spreaders		31.42	31.42

D. Agitator/pump operating time

1. pump number 1 199 MINS., tractors J.D. 2440
2. pump number 2 216 MINS., tractors J.D. 2440 + J.D. 4430

E. Performance data

1. minutes loading/M. ton (C1a ÷ B3) = 0.408
2. average kilometers/hour hauling $\left(\frac{B7 \times 60}{C1b}\right)$ = 10.06
3. minutes spreading/M. ton (C1c ÷ B3) = 0.562
4. M. tons loaded per liter (B3 ÷ C2a) = 0.633
5. M. ton-kilometers per liter fuel hauling and spreading $\left(\frac{B6 \times B7}{C2b}\right)$ = 4.30

F. Equipment used

1. Agitator/pump: manufacturer, model and tractor model, kW and fuel type used with pump

a. SAHLSTROM AGITATOR/PUMP WITH 44.8 KW 2440 J.D.
b. SAHLSTROM AGITATOR/PUMP WITH 44.8 KW 2440 J.D.
OR 94.0 KW 4430 J.D.
c.

2. Spreaders: liter (cubic meter) capacity, manufacturer, model and tractor model, kW and fuel type used with spreader

a. 3785 liter, Waymark liquid spreader with Oliver, Model 1850, 69.4
b. kw, diesel
c.

Prepared by: R. D. Martin Date: 8/23/82 Checked by: Alice Britt

(continued

APPENDIX C (continued)

TRIAL # L1A

Calculations

labor and machine input time (excluding weighing and idling time)

	total		average/load	
loading (pumping only)	16.530	mins.	1.6530	mins.
hauling	198.744	mins.	19.8744	mins.
spreading	22.783	mins.	2.2783	mins.
total time	238.057	mins.	23.8057	mins.
agitating time (machine only)	398	mins.	39.8	mins.

average round-trip hauling distance: $\frac{33.33}{10}$ $\frac{\text{km}}{\text{loads}}$ = 3.33 km/load

average hauling rate: $\frac{198.744}{33.33}$ $\frac{\text{mins.}}{\text{km}}$ = 5.96 mins./km

hauling time for various round-trip haul distances:

mins./kilometer		haul distance		time required
5.96	x	3.33	=	19.86
↓	x	0.8	=	4.82
↓	x	1.6	=	9.62
↓	x	2.4	=	14.42
↓	x	3.2	=	19.22
↓	x	4.0	=	24.02
↓	x	4.8	=	28.82

Time Per Load Requirement

round-trip hauling distance (kilometers)

	3.33	0.8	1.6	2.4	3.2	4.0	4.8
	minutes						
loading time	1.65	→	→	→	→	→	→
hauling time	19.86	4.82	9.62	14.42	19.22	24.02	
spreading time	2.28	→	→	→	→	→	→
total time	23.79	8.75	13.55	18.35	23.15	27.95	32.75

Prepared by: R.D. Martin Date: 8/23/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances

3.33 kilometers

$$\frac{23.79 \text{ mins./load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days} \times 60 \text{ mins./hour}} = 2.23 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
—	x	2.23	=	
50	x	↓	=	112
100	x	↓	=	223
150	x	↓	=	335
200	x	↓	=	446

0.8 kilometers

$$\frac{8.75 \text{ mins./load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days} \times 60 \text{ mins./hour}} = 0.82 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
—	x	0.82	=	
50	x	↓	=	41
100	x	↓	=	82
150	x	↓	=	123
200	x	↓	=	164

Prepared by: R. O. Martin Date: 8/23/82 Checked by: Alice Britt

(continued)

TRIAL # L1A

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances (continued)

1.6 kilometers

13.55 mins./load x 10 loads x 365 days/year = 1.27 hrs./cow year
649 cow days x 60 mins./hour

cow numbers		hrs./cow year		annual labor requirement
	x	1.27	=	
50	x		=	63
100	x		=	127
150	x		=	190
200	x		=	254

2.4 kilometers

18.35 mins./load x 10 loads x 365 days/year = 1.72 hrs./cow year
649 cow days x 60 mins./hour

cow numbers		hrs./cow year		annual labor requirement
	x	1.72	=	
50	x		=	86
100	x		=	172
150	x		=	258
200	x		=	344

Prepared by: R. O. Martin Date: 8/23/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances

3.2 kilometers

$$\frac{23.15 \text{ mins./load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days} \times 60 \text{ mins./hour}} = 2.17 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
	x	2.17	x	
50	x	↓	x	108
100	x		x	217
150	x		x	325
200	x		x	434

4.0 kilometers

$$\frac{27.95 \text{ mins./load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days} \times 60 \text{ mins./hour}} = 2.62 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
	x	2.62	=	
50	x	↓	=	131
100	x		=	262
150	x		=	393
200	x		=	523

Prepared by: R. D. Martin Date: 8/23/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances (continued)

4.8 kilometers

$$\frac{32.75 \text{ mins./load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days} \times 60 \text{ mins./hour}} = 3.07 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
—	x	3.07	=	
50	x		=	153
100	x		=	307
150	x		=	460
200	x		=	613

Prepared by: R. D. Martin Date: 8/23/82 Checked by: Alice Britt

(continued)

TRIAL # L1A

Calculation of Annual Fuel Requirements

liters of fuel input

	gasoline	diesel	total
tractors on pump/agitators		63.97	63.97
tractors on spreaders		31.42	31.42
totals		95.39	95.39

average fuel/load for agitating and pumping $\frac{63.97}{10}$ $\frac{\text{liters}}{\text{load}}$ =

6.40 liters/load

average fuel/kilometer* = $\frac{31.42 \text{ liters}}{10 \text{ loads} \times 3.33 \text{ km av./load}}$ =

0.943 liters/km

fuel required for various hauling distances*

fuel/kilometer		kilometers		liters
0.943	x	3.33	=	3.14
	x	0.8	=	0.75
	x	1.6	=	1.51
	x	2.4	=	2.27
	x	3.2	=	3.03
	x	4.0	=	3.79
	x	4.8	=	4.55

Fuel Per Load Requirement

round-trip haul distance

	3.33	0.8	1.6	2.4	3.2	4.0	4.8
pump agitator fuel	6.40						
haul & spread fuel*	3.14	0.75	1.51	2.27	3.03	3.79	4.55
	9.54	7.15	7.91	8.67	9.43	10.19	10.95

*assumes fuel consumption rate for hauling is the same as for spreading.

Prepared by: R. O. Martin Date: 8/24/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances

3.33 kilometers

$$\frac{9.54 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 53.64 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	53.64	=	
50	x	↓	=	2,684
100	x	↓	=	5,364
150	x	↓	=	8,048
200	x	↓	=	10,731

0.8 kilometers

$$\frac{7.15 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 40.24 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	40.24	=	
50	x	↓	=	2,014
100	x	↓	=	4,024
150	x	↓	=	6,038
200	x	↓	=	8,048

Prepared by: R. D. Martin Date: 8/24/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances (continued)

1.6 kilometers

$$\frac{7.91 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 44.52 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	44.52	=	
50	x	↓	=	2226
100	x		=	4452
150	x		=	6677
200	x		=	8903

2.4 kilometers

$$\frac{8.67 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 48.79 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	48.79	=	
50	x	↓	=	2438
100	x		=	4879
150	x		=	7317
200	x		=	9759

Prepared by: R. O. Martin Date: 8/24/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances (continued)

3.2 kilometers

$$\frac{9.43 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 53.07 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	53.07	=	
50	x	↓	=	2653
100	x	↓	=	5307
150	x	↓	=	7957
200	x	↓	=	10610

4.0 kilometers

$$\frac{10.19 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 57.31 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	57.31	=	
50	x	↓	=	2865
100	x	↓	=	5731
150	x	↓	=	8596
200	x	↓	=	11466

Prepared by: R. O. Martin Date: 8/24/82 Checked by: Alice Britt

(continued)

APPENDIX C (continued)

TRIAL # L1A

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances (continued)

4.8 kilometers

$$\frac{10.95 \text{ liters/load} \times 10 \text{ loads} \times 365 \text{ days/year}}{649 \text{ cow days}} = 61.59 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
—	x	61.59	=	
50	x		=	3081
100	x		=	6159
150	x		=	9240
200	x		=	12317

Prepared by: R. O. Martin Date: 8/24/82 Checked by: Alice Britt

APPENDIX D

Semisolid Storage and Handling of Manure -- Work Sheets for Calculating Annual Labor and Fuel Requirements

TRIAL #SS2

A. Barn Data

1. dates of trial period: MAY 10, 1976 - OCT. 12, 1976
2. number of days in trial: 156
3. total cow days in semisolid manure storage trial: 8069
4. average kilograms of milk produced per cow day: 25.98

B. Semisolid Manure Storage Data

1. cubic meters of manure in storage: 383
2. total kilograms of manure weighed out of storage: 363,348
3. average density of manure (B2 ÷ B1) = 949 kg/m3
4. distribution of manure from storage:

a.	used for calibration of spreader	—	kg
b.	used for test plots	* 19,959	kg
c.	used for timed unloading trial	363,348	kg
d.	total	363,348	kg

5. average kilograms of manure per cow day weighed out of storage (B2 ÷ A3) = 45 kg
6. total kilograms of manure weighed and timed out of storage (B4c): 363,348 kilograms, 363.3 M. tons
7. cow days in time trial (B6 ÷ B5) = 8069
8. average number of cows in time trial (B7 ÷ A2) = 51.72
9. total loads of manure hauled (from Form #135): 65
10. average weight per load (B6 ÷ B9) = 5,590 kilograms, 5.59 M. tons
11. total kilometers traveled by spreading tractors: 164.6
12. average kilometers travel per spreader, round-trip (11 ÷ 9) = 2.53

* The 19,959 kg of manure used on the test plot was part of the timed unloading.

(continued)

TRIAL # SS2

C. Labor and fuel data

1. incremental times (minutes) from Form #135

a. loading 340.135 mins.
b. hauling 727.571 mins.
c. spreading 160.700 mins.
d. weighing 164.814 mins.
e. idling ____ mins.

2. fuel input (liters from Form #131)

	gasoline	diesel	total
a. loading tractor	51.48	–	51.48
b. tractors on spreaders		148.38	148.38

D. Performance data

1. minutes loading/M. ton (C1a ÷ B6) = 0.936

2. average kilometers/hour, hauling $\frac{B11 \times 60}{C1b}$ = 13.57

3. minutes spreading/M. ton (C1c ÷ B6) = 0.442

4. M. tons loaded per liter (B6 ÷ C2a) = 7.057

5. M. ton-kilometers per liter of fuel hauling and spreading $\frac{B10 \times B11}{C2b}$ = 6.201

E. Equipment used

1. Loaders: manufacturer, model, fuel, kW, type and bucket size

a. CASE 1845, GASOLINE, 33.6 KW, SKID-STEER WITH
b. 0.67 m^3 BUCKET
c.

2. Spreaders: m^3, manufacturer, model -- Tractor, kW, manufacturer, model

a. 5.49 m^3 INTERNATIONAL HARVESTER 580
~~b.~~ SPREADER WITH 69.4 KW OLIVER 1850 TRACTOR.
c.
d.
e.

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

APPENDIX D (continued)

TRIAL #SS2

Calculations

labor and machine input time (excluding weighing and idling time)

	total		average/load	
loading	340.135	mins.	5.2328	mins.
hauling	727.571	mins.	11.1934	mins.
spreading	160.700	mins.	2.4723	mins.
total time	1228.4060	mins.	18.8985	mins.

avg. round-trip hauling distance: $\frac{164.6}{65}\ \frac{\text{km}}{\text{loads}} = 2.5317$ km/load

avg. hauling rate: $\frac{727.571}{164.6}\ \frac{\text{mins.}}{\text{km}} = 4.4214$ mins./km

hauling time for various round-trip haul distances:

mins./kilometer		haul distance		time required
4.4214	x	2.53	=	11.18
↓	x	0.8	=	3.56
↓	x	1.6	=	7.12
↓	x	2.4	=	10.68
↓	x	3.2	=	14.24
↓	x	4.0	=	17.79
↓	x	4.8	=	21.35

Time Per Load Requirement

round-trip hauling distance (kilometers)

	2.53	0.8	1.6	2.4	3.2	4.0	4.8
	minutes						
loading time	5.23	→	→	→	→	→	→
hauling time	11.18	3.56	7.12	10.68	14.24	17.79	21.35
spreading time	2.47	→	→	→	→	→	→
total time	18.88	11.26	14.82	18.38	21.94	25.49	29.05

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

TRIAL # 552

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances

2.53 kilometers

$$\frac{18.88 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = 0.925 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	0.925	=	48
50	x	↓	=	46
100	x		=	93
150	x		=	139
200	x		=	185

0.8 kilometers

$$\frac{11.26 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = 0.552 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	0.552	=	29
50	x	↓	=	28
100	x		=	55
150	x		=	83
200	x		=	110

Prepared by: R.O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

APPENDIX D (continued)

TRIAL # 552

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances (continued)

1.6 kilometers

$$\frac{14.82 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = 0.726 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	0.726	=	38
50	x	↓	=	36
100	x	↓	=	73
150	x	↓	=	109
200	x	↓	=	145

2.4 kilometers

$$\frac{18.38 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = 0.901 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	0.901	=	47
50	x	↓	=	45
100	x	↓	=	90
150	x	↓	=	135
200	x	↓	=	180

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

APPENDIX D (continued)

TRIAL # SS2

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances (continued)

3.2 kilometers

$$\frac{21.94 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = 1.075 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	1.075	=	56
50	x	↓	=	54
100	x		=	108
150	x		=	161
200	x		=	215

4.0 kilometers

$$\frac{25.49 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = 1.249 \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	1.249	=	65
50	x	↓	=	62
100	x		=	125
150	x		=	187
200	x		=	250

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

APPENDIX D (continued)

TRIAL #SS2

Calculations of Annual Labor Requirement For Various Size Herds and Hauling Distances (continued)

4.8 kilometers

$$\frac{29.05 \text{ mins./load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days} \times 60 \text{ mins./hour}} = \underline{1.424} \text{ hrs./cow year}$$

cow numbers		hrs./cow year		annual labor requirement
51.72	x	1.424	=	74
50	x	↓	=	71
100	x		=	142
150	x		=	214
200	x		=	285

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

TRIAL # SS2

Calculations of Annual Fuel Requirements

liters of fuel input	gasoline	diesel	total
loading tractor	51.48	—	51.48
tractors on spreaders		148.38	148.38
totals	51.48	148.38	199.86

average fuel/kilometer* = $\frac{148.38 \text{ liters}}{65 \text{ loads} \times 2.53 \text{ km av./load}}$ = .902 L/km

average fuel/load for loading = $\frac{51.48}{65}$ $\frac{\text{liters}}{\text{load}}$ = 0.792 L/load

fuel required for various hauling distances*

fuel/kilometer		kilometers		liters
0.902	x	2.53	=	2.28
↓	x	0.8	=	0.73
↓	x	1.6	=	1.45
↓	x	2.4	=	2.18
↓	x	3.2	=	2.90
↓	x	4.0	=	3.63
↓	x	4.8	=	4.36

Fuel Per Load Requirement
round-trip haul distance

	2.53	0.8	1.6	2.4	3.2	4.0	4.8
loading fuel	0.79	→					
haul & spread fuel*	2.28	0.73	1.45	2.18	2.90	3.63	4.36
	3.07	1.52	2.24	2.97	3.69	4.42	5.15

*assumes fuel consumption rate for hauling is the same as for spreading.

Prepared by: R. D. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

TRIAL # SS2

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances

2.53 kilometers

$$\frac{3.07 \text{ liters/load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days}} = 9.027 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
51.72	x	9.027	=	466
50	x	↓	=	450
100	x		=	901
150	x		=	1355
200	x		=	1805

0.8 kilometers

$$\frac{1.52 \text{ liters/load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days}} = 4.462 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
51.72	x	4.462	=	231
50	x	↓	=	223
100	x		=	447
150	x		=	670
200	x		=	893

Prepared by: R. D. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

TRIAL # 552

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances (continued)

1.6 kilometers

$$\frac{2.24 \text{ liters/load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days}} = 6.595 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
51.72	x	6.595	=	341
50	x	↓	=	329
100	x		=	659
150	x		=	988
200	x		=	1317

2.4 kilometers

$$\frac{2.97 \text{ liters/load} \times 65 \text{ loads} \times 365 \text{ days/year}}{8069 \text{ cow days}} = 8.729 \text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
51.72	x	8.729	=	450
50	x	↓	=	435
100	x		=	874
150	x		=	1310
200	x		=	1745

Prepared by: R. D. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

TRIAL # 552

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances (continued)

3.2 kilometers

3.69 liters/load x 65 loads x 365 days/year = 10.863 liters/cow year
8069 cow days

cow numbers		liters/cow year		annual liter requirement
51.72	x	10.863	=	560
50	x	↓	=	541
100	x		=	1086
150	x		=	1628
200	x		=	2173

4.0 kilometers

4.42 liters/load x 65 loads x 365 days/year = 12.996 liters/cow year
8069 cow days

cow numbers		liters/cow year		annual liter requirement
51.72	x	12.996	=	674
50	x	↓	=	651
100	x		=	1298
150	x		=	1949
200	x		=	2600

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

(continued)

APPENDIX D (continued)

TRIAL # 552

Calculations of Annual Fuel Requirements For Various Size Herds and Hauling Distances (continued)

4.8 kilometers

$$\frac{5.15\text{ liters/load x }65\text{ loads x 365 days/year}}{8069\text{ cow days}} = 15.130\text{ liters/cow year}$$

cow numbers		liters/cow year		annual liter requirement
51.72	x	15.130	=	783
50	x	↓	=	757
100	x	↓	=	1514
150	x	↓	=	2271
200	x	↓	=	3024

Prepared by: R. O. Martin Date: 4/2/81 Checked by: Alice Britt

APPENDIX E_1

Annual Labor and Fuel Requirements To Daily Haul and Spread As-Produced Manure Direct From Barn

TRIAL #DS 1

Elemental Time

Function	Minutes
Positioning spreader under barn cleaner	6.31 per day
Loading spreader	0.25 per cow day
Travel	6.57 per kilometer
Spreading	0.0575 per cow day

Fuel

Annual fuel per kilometer per cow = 13.45 liters

Round-Trip Hauling Distance (Kilometers)

Annual Labor Requirements

Cows	0.8	1.6	2.4
		Hours	
50	163	195	228
100	257	289	322
150	350	382	415

Annual Fuel Requirements

Cows	0.8	1.6	2.4
		Liters	
50	541	1,083	1,624
100	1,083	2,165	3,248
150	1,624	3,248	4,872

APPENDIX E_2

Annual Labor and Fuel Requirements To Daily Haul and Spread As-Produced Manure Direct From Barn

TRIAL #DS 2

Elemental Time

Function	Minutes
Positioning spreader under barn cleaner	5.16 per day
Loading spreader	0.23 per cow day
Travel	9.18 per kilometer
Spreading	0.0634 per cow day

Fuel

Annual fuel per kilometer per cow = 16.51 liters

Round-Trip Hauling Distance (Kilometers)

Annual Labor Requirements

Cows	0.8	1.6	2.4
		Hours	
50	165	210	255
100	255	300	345
150	344	389	434

Annual Fuel Requirements

Cows		Liters	
50	666	1,329	1,995
100	1,329	2,657	3,986
150	1,995	3,986	5,981

APPENDIX B_3

Annual Labor and Fuel Requirements To Daily Haul and Spread As-Produced Manure Direct From Barn

TRIAL #DS 3

Elemental Time

Function	Minutes	
Positioning spreader under barn cleaner	4.72	per day
Loading spreader	0.214	per cow day
Travel	6.57	per kilometer
Spreading	0.068	per cow day

Fuel

Annual fuel per kilometer per cow = 11.90 liters

Round-Trip Hauling Distance (Kilometers)

Annual Labor Requirements

Cows	0.8	1.6	2.4
	Hours		
50	147	179	212
100	232	264	297
150	318	350	383

Annual Fuel Requirements

Cows	0.8	1.6	2.4
	Liters		
50	481	958	1,438
100	958	1,915	2,873
150	1,438	2,873	4,311

APPENDIX E_4

Annual Labor and Fuel Requirements To Daily Haul and Spread As-Produced Manure Direct From Barn

TRIAL #DS 4

Elemental Time

Function	Minutes
Positioning spreader under barn cleaner	3.01 per day
Loading spreader	0.213 per cow day
Travel	7.45 per kilometer
Spreading	0.0445 per cow day

Fuel

Annual fuel per kilometer per cow = 7.27 liters

Round-Trip Hauling Distance (Kilometers)

Annual Labor Requirements

Cows	0.8	1.6	2.4
	Hours		
50	133	170	206
100	211	248	284
150	289	326	362

Annual Fuel Requirements

Cows	0.8	1.6	2.4
	Liters		
50	291	587	878
100	587	1,170	1,756
150	874	1,756	2,631

APPENDIX B_5

Annual Labor and Fuel Requirements To Daily Haul and Spread As-Produced Manure Direct From Barn

TRIAL #DS 5

Elemental Time

Function	Minutes
Positioning spreader under barn cleaner	3.07 per day
Loading spreader	0.217 per cow day
Travel	5.80 per kilometer
Spreading	0.0537 per cow day

Fuel

Annual fuel per kilometer per cow = 8.40 liters

Round-Trip Hauling Distance (Kilometers)

Annual Labor Requirements

Cows	Hours 0.8	Hours 1.6	Hours 2.4
50	129	158	186
100	212	241	269
150	294	323	351

Annual Fuel Requirements

Cows	Liters 0.8	Liters 1.6	Liters 2.4
50	337	678	1,014
100	678	1,351	2,029
150	1,014	2,029	3,040

APPENDIX E_6

Annual Labor and Fuel Requirements To Daily Haul and Spread As-Produced Manure Direct From Barn

TRIAL #DS 6

Elemental Time

Function	Minutes	
Positioning spreader under barn cleaner	3.14	per day
Loading spreader	0.217	per cow day
Travel	5.75	per kilometer
Spreading	0.0406	per cow day

Fuel

Annual fuel per kilometer per cow = 7.39 liters

Round-Trip Hauling Distance (Kilometers)

	0.8	1.6	2.4
Annual Labor Requirements			
Cows		Hours	
50	125	153	181
100	204	232	260
150	282	310	338
Annual Fuel Requirements			
Cows		Liters	
50	299	594	893
100	594	1,189	1,783
150	893	1,783	2,676

APPENDIX F_1

Annual Labor and Fuel Required to Agitate, Load, Haul and Spread Liquid Manure From Below-Ground Concrete Storage

TRIAL L1A

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	3.33	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	1.65	1.65	1.65	1.65	1.65	1.65	1.65
Travel	19.86	4.80	9.60	14.39	19.19	23.99	28.79
Spreading	2.28	2.28	2.28	2.28	2.28	2.28	2.28
Total	23.79	8.73	13.53	18.32	23.12	27.92	32.72

Annual Labor Requirements

Cows							
	Hours						
50	112	41	63	86	108	131	153
100	223	82	127	172	217	262	307
150	335	123	190	258	325	393	460
200	446	164	254	344	434	523	613

Annual Fuel Requirements

Cows							
	Liters						
50	2,684	2,014	2,226	2,438	2,653	2,865	3,081
100	5,364	4,024	4,452	4,879	5,307	5,731	6,159
150	8,048	6,038	6,677	7,317	7,957	8,596	9,240
200	10,731	8,048	8,903	9,759	10,610	11,466	12,317

APPENDIX F_2

Annual Labor and Fuel Required to Agitate, Load, Haul and Spread Liquid Manure From Below-Ground Concrete Storage

TRIAL L1B

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	4.20	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	2.16	2.16	2.16	2.16	2.16	2.16	2.16
Travel	18.04	3.46	6.91	10.37	13.83	17.28	20.74
Spreading	3.85	3.85	3.85	3.85	3.85	3.85	3.85
Total	24.05	9.47	12.92	16.38	19.84	23.29	26.75

Annual Labor Requirements

Cows				Hours			
50	97	38	52	66	80	94	108
100	194	76	104	132	160	187	215
150	290	114	156	198	239	281	323
200	387	152	208	264	319	375	431

Annual Fuel Requirements

Cows				Liters			
50	2,869	2,006	2,211	2,415	2,619	2,824	3,028
100	5,735	4,016	4,425	4,830	5,239	5,648	6,053
150	8,604	6,022	6,636	7,245	7,858	8,468	9,081
200	11,473	8,032	8,846	9,660	10,478	11,292	12,109

APPENDIX F_3

Annual Labor and Fuel Required to Agitate, Load, Haul and Spread Liquid Manure From Below-Ground Concrete Storage

TRIAL L2A

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	4.67	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	2.21	2.21	2.21	2.21	2.21	2.21	2.21
Travel	16.81	2.90	5.80	8.70	11.59	14.49	17.39
Spreading	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Total	21.32	7.41	10.31	13.21	16.10	19.00	21.90

Annual Labor Requirements

Cows	Hours						
50	156	54	75	97	118	139	160
100	312	108	151	193	236	278	321
150	468	163	226	290	354	417	481
200	624	217	302	387	471	556	641

Annual Fuel Requirements

Cows	Liters						
50	3,267	2,241	2,453	2,668	2,881	3,093	3,308
100	6,530	4,478	4,906	5,333	5,761	6,189	6,617
150	9,796	6,719	7,359	8,002	8,642	9,282	9,925
200	13,063	8,956	9,811	10,667	11,522	12,378	13,233

APPENDIX F_4

Annual Labor and Fuel Required to Agitate, Load, Haul and Spread Liquid Manure From Below-Ground Concrete Storage

TRIAL L2B

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	5.18	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	2.49	2.49	2.49	2.49	2.49	2.49	2.49
Travel	16.30	2.53	5.06	7.59	10.12	12.65	15.18
Spreading	4.76	4.76	4.76	4.76	4.76	4.76	4.76
Total	23.55	9.78	12.31	14.84	17.37	19.90	22.43

Annual Labor Requirements

Cows				Hours			
50	129	53	67	81	95	109	122
100	257	107	134	162	190	217	245
150	386	160	202	243	284	326	367
200	514	214	269	324	379	435	490

Annual Fuel Requirements

Cows				Liters			
50	3,414	2,245	2,460	2,676	2,888	3,104	3,320
100	6,829	4,489	4,917	5,349	5,780	6,212	6,639
150	10,243	6,730	7,378	8,025	8,668	9,316	9,959
200	13,661	8,975	9,838	10,697	11,560	12,420	13,279

APPENDIX F_5

Annual Labor and Fuel Required to Agitate, Load, Haul and Spread Liquid Manure From Below-Ground Concrete Storage

TRIAL L3A

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.53	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	2.59	2.59	2.59	2.59	2.59	2.59	2.59
Travel	10.97	3.49	6.99	10.48	13.97	17.46	20.96
Spreading	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Total	14.68	7.20	10.70	14.19	17.68	21.17	24.67

Annual Labor Requirements

Cows	Hours						
50	57	28	42	55	69	82	96
100	114	56	83	110	137	165	192
150	171	84	125	165	206	247	288
200	228	112	166	221	275	329	384

Annual Fuel Requirements

Cows	Liters						
50	2,627	2,237	2,419	2,601	2,782	2,968	3,149
100	5,254	4,470	4,838	5,201	5,568	5,932	6,299
150	7,881	6,708	7,253	7,802	8,350	8,899	9,448
200	10,504	8,941	9,671	10,402	11,133	11,867	12,597

APPENDIX F_6

Annual Labor and Fuel Required to Agitate, Load, Haul and Spread Liquid Manure From Below-Ground Concrete Storage

TRIAL L3B

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.53	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Travel	9.84	3.13	6.27	9.40	12.53	15.67	18.80
Spreading	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total	15.04	8.33	11.47	1460	17.73	20.87	24.00

Annual Labor Requirements

Cows				Hours			
50	35	20	27	34	42	49	56
100	71	39	54	69	83	98	113
150	106	59	81	103	125	147	169
200	142	78	108	137	167	196	226

Annual Fuel Requirements

Cows				Liters			
50	2,551	2,207	2,370	2,529	2,691	2,854	3,013
100	5,103	4,414	4,735	5,061	5,383	5,704	6,030
150	7,658	6,617	7,105	7,590	8,074	8,559	9,043
200	10,209	8,824	9,471	10,118	10,765	11,413	12,060

APPENDIX G_1

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #1 (Oct. 26, '75 - May 9, '76)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.69	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Travel	13.87	4.15	8.31	12.46	16.61	20.77	24.92
Spreading	3.84	3.84	3.84	3.84	3.84	3.84	3.84
Total	19.61	9.89	14.05	18.20	22.35	26.51	30.66

Annual Labor Requirements

Cows				Hours			
56.8	84	42	60	78	95	113	131
50	74	37	53	68	84	100	115
100	147	74	105	137	168	199	230
150	221	111	158	205	252	299	345
200	295	149	211	273	336	398	460

Annual Fuel Requirements

Cows				Liters			
56.8	836	371	572	772	969	1,170	1,366
50	738	329	503	681	852	1,030	1,204
100	1,476	655	1,007	1,363	1,707	2,055	2,407
150	2,214	984	1,510	2,044	2,559	3,085	3,611
200	2,949	1,310	2,010	2,721	3,414	4,114	4,815

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 33.6 kW Case model 1845 steer-skid loader with 0.67 m^3 bucket. Spreaders and tractors included: a 2.30 m^3 John Deere model 23 spreader hauled by a 33.6 kW John Deere model 2010 or a 53.7 kW Leyland model 272 tractor, a 5.43 m^3 International Harvester model 580 spreader hauled by a 69.4 kW Oliver model 1850 tractor, a 4.51 m^3 Badger model BN 240 spreader hauled by an 59.7 kW International Harvester model 826 tractor, a 4.20 m^3 New Holland model 676 spreader hauled by a 53.7 kW International Harvester model 706 tractor, and a 4.59 m^3 New Idea model 218 spreader hauled by a 59.7 kW John Deere model 4030 tractor.

APPENDIX G$_2$

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #2 (May 10, '76 - Oct. 12, '76)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.53	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	5.23	5.23	5.23	5.23	5.23	5.23	5.23
Travel	11.17	3.56	7.12	10.67	14.23	17.79	21.35
Spreading	2.47	2.47	2.47	2.47	2.47	2.47	2.47
Total	18.87	11.26	14.82	18.37	21.93	25.49	29.05

Annual Labor Requirements

Cows	2.53	0.8	1.6	2.4	3.2	4.0	4.8
	Hours						
51.7	48	29	38	47	56	65	74
50	46	28	36	45	54	62	71
100	93	55	73	90	108	125	142
150	139	83	109	135	161	187	214
200	185	110	145	180	215	250	285

Annual Fuel Requirements

Cows	2.53	0.8	1.6	2.4	3.2	4.0	4.8
	Liters						
51.7	466	231	341	450	560	674	783
50	450	223	329	435	541	651	757
100	901	447	659	874	1,086	1,298	1,514
150	1,355	670	988	1,310	1,628	1,949	2,271
200	1,805	893	1,317	1,745	2,173	2,600	3,024

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 33.6 kW Case model 1845 steer-skid loader with 0.67 m^3 bucket to load a 5.43 m^3 International Harvester model 580 spreader hauled by a 69.4 kW Oliver model 1850 tractor.

APPENDIX G_3

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #3A (Oct. 13, '76 - May 4, '77)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	5.44	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	8.78	8.78	8.78	8.78	8.78	8.78	8.78
Travel	23.43	3.47	6.93	10.40	13.86	17.33	20.80
Spreading	9.34	9.34	9.34	9.34	9.34	9.34	9.34
Total	41.55	21.59	25.05	28.52	31.98	35.45	38.92

Annual Labor Requirements

Cows	Hours						
25.6	30	15	18	20	23	25	28
50	58	30	35	40	45	50	54
100	116	60	70	80	89	99	109
150	174	90	105	120	134	149	163
200	232	121	140	159	179	198	217

Annual Fuel Requirements

Cows	Liters						
25.6	799	246	344	439	534	628	727
50	1,560	485	670	855	1,041	1,230	1,416
100	3,115	965	1,340	1,711	2,086	2,460	2,831
150	4,675	1,450	2,010	2,570	3,127	3,687	4,247
200	6,231	1,931	2,676	3,426	4,171	4,917	5,663

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a Caterpillar model 966B payloader with 2.7 m^3 bucket to load a 10.4 m^3 Agway 4.9 m tandem axle fertilizer/lime spreader truck.

APPENDIX G$_4$

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #3B (Oct. 13, '76 - May 4, '77)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	3.67	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	5.27	5.27	5.27	5.27	5.27	5.27	5.27
Travel	15.40	3.38	6.75	10.13	13.50	16.88	20.26
Spreading	1.98	1.98	1.98	1.98	1.98	1.98	1.98
Total	22.65	10.63	14.00	17.38	20.75	24.13	27.51

Annual Labor Requirements

Cows				Hours			
9	10	5	6	8	9	11	12
50	57	27	35	43	52	60	69
100	113	53	70	87	104	121	138
150	170	80	105	130	156	181	206
200	226	106	140	174	207	241	275

Annual Fuel Requirements

Cows				Liters			
9	102	38	57	76	91	110	129
50	572	212	310	413	515	617	715
100	1,143	420	625	825	1,030	1,230	1,435
150	1,711	632	935	1,238	1,544	1,847	2,150
200	2,283	844	1,249	1,654	2,055	2,460	2,865

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 33.6 kW Case model 1845 steer-skid loader with 0.67 m^3 bucket to load a 5.49 m^3 International Harvester model 580 spreader hauled by a 69.4 kW Oliver model 1850 tractor.

APPENDIX G5

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #4A (May 5, '77 - Oct. 28, '77)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.69	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	5.95	5.95	5.95	5.95	5.95	5.95	5.95
Travel	14.09	4.22	8.44	12.66	16.88	21.10	25.32
Spreading	2.43	2.43	2.43	2.43	2.43	2.43	2.43
Total	22.47	12.60	16.82	21.04	25.26	29.48	33.70

Annual Labor Requirements

Cows	Hours						
18.3	22	12	16	20	24	28	32
50	59	33	44	55	67	78	89
100	118	66	89	111	133	155	178
150	178	100	133	166	200	233	266
200	237	133	177	222	266	311	355

Annual Fuel Requirements

Cows	Liters						
18.3	132	61	91	125	155	185	220
50	367	163	250	337	424	511	598
100	734	329	503	674	848	1,022	1,196
150	1,102	492	753	1,014	1,272	1,533	1,790
200	1,469	659	1,003	1,351	1,696	2,044	2,389

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 46.3 kW New Holland model L778 steer-skid loader with 0.59 m^3 bucket to load a 5.49 m^3 International Harvester model 580 spreader (capacity of 5.49 m^3 spreader increased to 7.11 m^3 by addition of one 5.1 cm x 25.4 cm plank on each side) hauled by a 44.8 kW John Deere model 2440 tractor.

APPENDIX G_6

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #4B (May 5, '77 - Oct. 28, '77)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.77	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	8.66	8.66	8.66	8.66	8.66	8.66	8.66
Travel	13.95	4.06	8.11	12.16	16.22	20.27	24.33
Spreading	3.21	3.21	3.21	3.21	3.21	3.21	3.21
Total	25.82	15.93	19.98	24.03	28.09	32.14	36.20

Annual Labor Requirements

Cows	Hours						
23.3	20	13	16	19	22	25	29
50	44	27	34	41	48	55	61
100	88	54	68	82	95	109	123
150	131	81	102	122	143	164	184
200	175	108	136	163	191	218	246

Annual Fuel Requirements

Cows	Liters						
23.3	182	79	121	163	208	250	291
50	394	170	261	352	443	538	628
100	787	341	522	704	890	1,071	1,257
150	1,181	507	784	1,060	1,332	1,609	1,885
200	1,575	678	1,045	1,412	1,779	2,146	2,510

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 46.3 kW New Holland model L778 steer-skid loader with 0.59 m^3 bucket to load a 0.72 m^3 New Holland model 780 spreader hauled by a 69.4 kW Oliver model 1850 tractor.

APPENDIX G_7

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #5A (Oct. 29, '77 - April 27, '78)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	4.30	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	11.17	11.17	11.17	11.17	11.17	11.17	11.17
Travel	22.39	4.19	8.39	12.58	16.77	20.97	25.16
Spreading	2.97	2.97	2.97	2.97	2.97	2.97	2.97
Total	36.53	18.33	22.53	26.72	30.91	35.11	39.30

Annual Labor Requirements

Cows	Hours						
23.6	34	17	21	25	29	33	37
50	73	37	45	53	62	70	78
100	146	73	90	107	123	140	157
150	219	110	135	160	185	210	235
200	292	146	180	213	247	280	314

Annual Fuel Requirements

Cows	Liters						
23.6	280	72	121	167	216	265	314
50	598	151	254	356	462	564	666
100	1,196	303	507	715	920	1,128	1,332
150	1,794	454	765	1,071	1,382	1,692	1,999
200	2,392	606	1,018	1,431	1,843	2,252	2,665

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 31.3 kW Bobcat model 825 steer-skid loader with 0.57 m^3 bucket to load a 7.87 m^3 Martin model V-2100 spreader hauled by a 69.4 kW Oliver model 1850 tractor (loads 1-5) or a 94.0 kW John Deere model 4430 tractor (loads 6-28).

APPENDIX G_8

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #5B (Oct. 29, '77 - April 27, '78)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes					
Loading	7.47	7.47	7.47	7.47	7.47	7.47
Travel	4.08	8.16	12.24	16.32	20.40	24.48
Spreading	2.67	2.67	2.67	2.67	2.67	2.67
Total	14.22	18.30	22.38	26.46	30.54	34.62

Annual Labor Requirements

Cows	Hours					
10.3	7	9	11	12	14	16
50	32	42	51	60	69	79
100	65	83	102	120	139	157
150	97	125	153	181	208	236
200	129	167	204	241	278	315

Annual Fuel Requirements

Cows	Liters					
10.3	34	57	79	102	125	148
50	159	269	379	488	598	704
100	314	534	753	973	1,192	1,412
150	473	802	1,132	1,461	1,790	2,116
200	632	1,071	1,507	1,946	2,385	2,824

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 31.3 kW Bobcat model 825 steer-skid loader with 0.57 m^3 bucket to load a 5.49 m^3 International Harvester model 580 spreader (capacity of 5.49 m^3 spreader increased to 7.11 m^3 by addition of one 5.1 cm x 25.4 cm plank on each side) hauled by a 94.0 kW John Deere model 4430 tractor.

APPENDIX G$_9$

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #6A (April 28, '78 - Oct. 27, '78)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	3.27	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	8.02	8.02	8.02	8.02	8.02	8.02	8.02
Travel	12.64	3.11	6.23	9.34	12.46	15.57	18.68
Spreading	3.31	3.31	3.31	3.31	3.31	3.31	3.31
Total	23.97	14.44	17.56	20.67	23.79	26.90	30.01

Annual Labor Requirements

Cows	Hours						
19.3	20	12	15	17	20	22	25
50	52	31	38	44	51	58	65
100	103	62	75	89	102	116	129
150	155	93	113	133	153	173	194
200	206	124	151	178	205	231	258

Annual Fuel Requirements

Cows	Liters						
19.3	265	95	151	208	265	318	375
50	689	246	390	538	681	825	973
100	1,382	492	784	1,071	1,363	1,654	1,942
150	2,071	738	1,173	1,609	2,044	2,479	2,915
200	2,759	984	1,567	2,146	2,725	3,305	3,884

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 44.8 kW International Harvester model 484 steer-skid loader with 0.76 m^3 bucket to load a 7.87 m^3 Martin model V-2100 spreader hauled by a 94.0 kW John Deere model 4430 tractor.

APPENDIX G_{10}

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #6B (April 28, '78 - Oct. 27, '78)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	2.93	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	6.83	6.83	6.83	6.83	6.83	6.83	6.83
Travel	13.53	3.72	7.43	11.15	14.87	18.58	22.30
Spreading	2.59	2.59	2.59	2.59	2.59	2.59	2.59
Total	22.95	13.14	16.85	20.57	24.29	28.00	31.72

Annual Labor Requirements

Cows				Hours			
15	16	9	12	14	17	20	22
50	53	31	39	48	56	65	74
100	107	61	78	96	113	130	147
150	160	92	118	143	169	195	221
200	213	122	157	191	226	260	295

Annual Fuel Requirements

Cows				Liters			
15	151	64	98	132	167	197	231
50	507	212	326	435	549	659	772
100	1,014	424	647	874	1,098	1,321	1,544
150	1,525	636	973	1,310	1,647	1,980	2,317
200	2,033	852	1,298	1,745	2,195	2,642	3,089

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 44.8 kW International Harvester model 484 steer-skid loader with 0.76 m^3 bucket to load a 5.49 m^3 International Harvester model 580 spreader (capacity of 5.49 m^3 spreader increased to 7.11 m^3 by addition of one 5.1 cm x 25.4 cm plank on each side) hauled by a 69.4 kW Oliver model 1850 tractor.

APPENDIX G_{11}

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #7A (Oct. 28, '78 - April 23, '79)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	4.47	0.8	1.6	2.4	3.2	4.0	4.8
				Minutes			
Loading	6.61	6.61	6.61	6.61	6.61	6.61	6.61
Travel	17.89	3.22	6.44	9.65	12.87	16.09	19.31
Spreading	3.02	3.02	3.02	3.02	3.02	3.02	3.02
Total	27.52	12.85	16.07	19.28	22.50	25.72	28.94

Annual Labor Requirements

Cows				Hours			
20.4	27	13	16	19	22	25	29
50	67	31	39	47	54	62	70
100	133	62	78	93	109	124	140
150	200	93	117	140	163	187	210
200	266	124	155	187	218	249	280

Annual Fuel Requirements

Cows				Liters			
20.4	276	95	136	174	216	254	291
50	678	235	333	428	526	621	719
100	1,351	469	662	855	1,052	1,245	1,438
150	2,029	704	996	1,287	1,575	1,866	2,158
200	2,706	939	1,325	1,715	2,101	2,491	2,877

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 32.8 kW Bobcat model 825 steer-skid loader with 0.38 m^3 bucket or a 33.6 kW Case model 1845 steer-skid loader with 0.67 m^3 bucket to load a 5.49 m^3 International Harvester model 580 spreader (capacity of 5.49 m^3 spreader increased to 7.11 m^3 by addition of one 5.1 cm x 25.4 cm plank on each side) hauled by a 69.4 kW Oliver model 1850 tractor.

APPENDIX G_{12}

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #7B (Oct. 28, '79 - April 23, '79)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	4.80	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	7.20	7.20	7.20	7.20	7.20	7.20	7.20
Travel	15.31	2.57	5.14	7.71	10.27	12.84	15.41
Spreading	3.45	3.45	3.45	3.45	3.45	3.45	3.45
Total	25.96	13.22	15.79	18.36	20.92	23.49	26.06

Annual Labor Requirements

Cows	Hours						
18.3	23	12	14	16	18	21	23
50	63	32	38	44	51	57	63
100	126	64	76	89	101	114	126
150	188	96	115	133	152	170	189
200	251	128	153	178	202	227	252

Annual Fuel Requirements

Cows	Liters						
18.3	299	91	132	174	216	257	299
50	814	250	363	477	594	708	821
100	1,631	503	731	958	1,185	1,412	1,639
150	2,445	753	1,094	1,435	1,779	2,120	2,460
200	3,259	1,007	1,461	1,915	2,370	2,824	3,278

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 32.8 kW Bobcat model 825 steer-skid loader with 0.38 m^3 bucket or a 33.6 kW Case model 1845 steer-skid loader with 0.67 m^3 bucket to load a 5.97 m^3 International Harvester model 595 spreader hauled by a 94.0 kW John Deere model 4430 tractor.

APPENDIX G_{13}

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #8A (April 24, '79 - Oct. 21, '79)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	0.72	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	7.17	7.17	7.17	7.17	7.17	7.17	7.17
Travel	6.38	4.43	8.87	13.30	17.73	22.17	26.60
Spreading	2.38	2.38	2.38	2.38	2.38	2.38	2.38
Total	15.93	13.98	18.42	22.85	27.28	31.72	36.15

Annual Labor Requirements

Cows	Hours						
20.7	16	14	18	22	27	31	35
50	38	33	43	54	64	75	85
100	75	66	87	108	129	150	171
150	113	99	130	162	193	224	256
200	150	132	174	216	257	299	341

Annual Fuel Requirements

Cows	Liters						
20.7	87	68	114	159	204	250	295
50	215	167	276	386	492	602	712
100	432	333	553	768	988	1,204	1,423
150	647	503	829	1,155	1,480	1,809	2,135
200	859	666	1,105	1,541	1,976	2,411	2,847

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 32.8 kW Bobcat model 825 steer-skid loader with 0.69 m^3 bucket to load a 5.49 m^3 International Harvester model 580 spreader (capacity of 5.49 m^3 spreader increased to 7.11 m^3 by addition of one 5.1 cm x 25.4 cm plank on each side) hauled by a 44.8 kW John Deere model 2440 tractor.

APPENDIX G_{14}

Annual Labor and Fuel Required to Unload, Haul and Spread Semisolid Manure From Storage*

BASED ON TRIAL #8B (April 24, '79 - Oct. 21, '79)**

Time Per Load Requirements

Round-Trip Hauling Distance (Kilometers)

Function	1.19	0.8	1.6	2.4	3.2	4.0	4.8
	Minutes						
Loading	7.57	7.57	7.57	7.57	7.57	7.57	7.57
Travel	6.70	4.53	9.05	13.57	18.10	22.62	27.15
Spreading	2.85	2.85	2.85	2.85	2.85	2.85	2.85
Total	17.12	14.95	19.47	23.99	28.52	33.04	37.57

Annual Labor Requirements

Cows	Hours						
21	17	15	20	24	29	33	38
50	41	36	47	58	68	79	90
100	82	72	93	115	137	159	180
150	123	108	140	173	205	238	270
200	164	143	187	230	274	317	361

Annual Fuel Requirements

Cows	Liters						
21	91	68	114	155	201	246	288
50	212	163	269	371	477	583	685
100	428	326	534	746	954	1,162	1,370
150	640	488	802	1,117	1,431	1,741	2,055
200	852	651	1,071	1,488	1,908	2,324	2,741

*Six months roof-covered manure storage unloaded spring and fall.

**Based on actual experience at the Agway Farm Research Center using a 32.8 kW Bobcat model 825 steer-skid loader with 0.69 m^3 bucket to load a 5.97 m^3 International Harvester model 595 spreader hauled by a 44.8 kW John Deere model 2440 tractor.

APPENDIX H

Investment Information Used to Compare Annual Cost of Three Manure Management Systems

1. Ralco barn cleaner with straight out discharge to loading shed on end of barn (use 2.44 m beam) --

   - Length of chain required to discharge into spreader (meters):

     50 cow barn = ((25 stalls x 1.22) + 1.22)2 + 4.88 + 8.53 = 76.85
     100 cow barn = ((50 stalls x 1.22) + 2.44)2 + 4.88 + 8.53 = 140.29
     150 cow barn = ((75 stalls x 1.22) + 3.66)2 + 4.88 + 8.53 = 203.73

	Cows		
	50	100	150
1 transmission	$ 1,296	$ 1,296	$ 1,296
1 beam 2.44 m	596	596	596
1 concrete kit	679	679	679
chain @ $32.12/m			
76.85 meters	2,467		
140.29 meters		4,504	
203.73 meters			6,540
motor			
1.49 kilowatts	199		
2.24 kilowatts		265	
3.73 kilowatts			355
installation w/electrical	595	742	989
	$ 5,832	$ 8,082	$10,455

   - Length of chain can be reduced 2.44 m when discharging into a ram hopper or reception pit for a chopper pump ($78).

2. Loading shed 4.88 m x 10.97 m with 3.66 m x 3.05 m overhead door, concrete floor and ramp ($7,500).

3. Box manure spreaders with tail gate

   - 50 cow system required 3.54 m^3 spreader with 52.2 kW tractor. $7,100 for New Holland.

   - 100 cow system required 6.37 m^3 spreader and 74.6 kW tractor. $10,450 for New Holland.

   - 150 cow system required 9.20 m^3 spreader and 93.3 kW tractor. $17,000 for New Holland.

(continued)

4. Martin spreaders (tractor size required)

Model 1666	5.66 m^3	$12,202*,	67.1 to 74.6 kW
Model 1678	8.50 m^3	$12,852*,	74.6 + kW

5. Installation Cost of Ralco Model 955 Ram

955 ram	$ 2,695
power pack	2,539
113.6 liters oil	150
single hopper	205
	$ 5,589
8 hours backhoe @ $30	240
32 hours labor @ $15	480
6.12 m^3 concrete @ $58.82	360
electrical	250
use $6,900	$ 6,919

6. Installation Cost of 30.5 cm PVC Pipe (30.5 meters)

30.5 meters of pipe @ $26.25/m	$ 800
8 hours backhoe @ $30	240
16 hours labor @ $15	240
1.53 m^3 concrete @ $58.82	90
use $1,400	$ 1,370

7. Installation Cost of Flygt Cutter Pump

Model 3152 Flygt pump (14.9 kW, 3 phase) including electrical control and 7.62 m of cable	$ 7,355
base unit, nozzle, ball check valve and accessories	1,538
mast and chain falls	200
labor for installation in reception pit	120
electrical -- 60 amp circuit breaker and 60.96 m service cable at $5.33/m	325
use $9,550	$ 9,538

8. Installation Cost of 15.2 cm Fiberglass Pipe (30.5 meters)

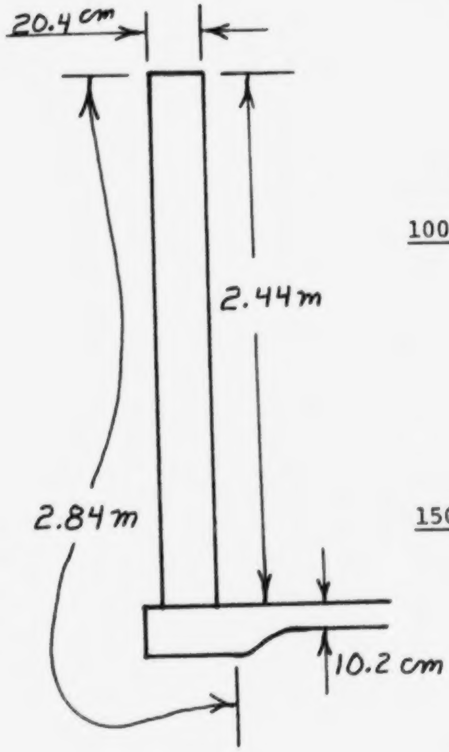
30.5 meters of pipe @ $8.86/m	$ 270
8 hours backhoe @ $30	240
8 hours labor @ $15	120
3.8 liters cement	20
use $650	$ 650

(continued)

9. Reception Pit Cost

- Size for 3 days storage with 0.91 meter residual in pit at all times and 0.30 meter freeboard (overall height of 2.44 meters). Effective storage height = 1.22 meters.
- Use 7.6 cm thick bridge plank for cover.

Herd Size	Cubic Meters Required	Outside Dimensions (meters)	Actual Storage Capacity (m^3)
50	7.65	2.44 x 3.66 x 2.44	8.07
100	15.29	3.66 x 4.27 x 2.44	15.32
150	22.94	3.66 x 6.10 x 2.44	22.57



50 cows 2.84 m x 0.204 m x 11.58 m = 6.71 m^3

floor = 8.92 m^2 -- 9.84 m^2/m^3 = 0.91 m^3

10% slop = 0.80 m^3

Total concrete 8.42 m^3

8.92 m^2 of 7.6 cm thick bridge plank

100 cows 2.84 m x 0.204 m x 15.24 m = 8.83 m^3

floor = 15.61 m^2 -- 9.84 m^2/m^3 = 1.59 m^3

10% slop = 1.59 m^3

Total concrete 11.48 m^3

15.61 m^2 of 7.6 cm thick bridge plank

150 cows 2.84 m x 0.204 m x 18.90 m = 10.95 m^3

floor = 22.30 m^2 -- 9.84 m^2/m^3 = 2.27 m^3

10% slop = 1.32 m^3

Total concrete 14.54 m^3

22.30 m^2 of 7.6 cm thick bridge plank

(continued)

9. Reception Pit Cost (cont)

- Reception Pit Cost Summary

Cows	Size (meters)	Concrete in Place	Bridge Plank[2]	Excavation	Backfill	Labor for Cover	Total
50	2.44 x 3.66 x 2.44	$1,650	$202	$ 75	$25	$ 120	$2,072
100	3.66 x 4.27 x 2.44	2,250	353	100	25	180	2,908
150	3.66 x 6.10 x 2.44	2,850	504	125	25	240	3,744

1. allow $196 per cubic meter

2. allow $22.65 per square meter of 7.6 cm thick bridge plank

Allow 15% for margin and supervision --

Use the following for estimating:

50 cows	$2,400
100 cows	3,400
150 cows	4,400

10. Roof-Covered Manure Storage For Semisolid Manure
(timber column construction) 6 months storage

	COWS		
	50	100	150
cubic meters required	459	918	1377
size (3.05 meter storage height)	15.24 m x 9.75 m	15.24 m x 19.51 m	18.29 m x 24.38 m
side walls @ $278.59/m	$ 2,720	$ 5,440	$ 6,800
roof @ $410.10/m	4,000	8,000	12,000
back wall	2,100	2,100	2,520
front wall	2,950	2,950	3,370
bulkhead	1,600	1,600	1,600
floor @ \$16.15/m^2	2,400	4,800	7,200
	$15,770	$24,890	$33,490
contingency	1,577	2,489	3,349
	$17,347	$24,379	$36,839
Use	$17,350	$24,400	$36,850

(continued)

11. Glass Fused to Steel, Tub Silo Liquid Manure Storage for 6 Months Storage

- Storage requirements to store 54.25 kg of manure at 17.3% dry matter (density of 993 kg/m^3) per cow day diluted with added water and precipitation to 12% dry matter.

- Per cow = $\frac{54.25}{993} \times 182.5 \text{ days} \times \frac{0.173}{0.12} = 14.37 \text{ m}^3$

Cows	Capacity - m^3	Capacity - Liters
50	719	719,000
100	1,438	1,438,000
150	2,157	2,157,000

- Tub silo size and cost

Cows	Size - Meters	Capacity Liters	Concrete Cost	Tub Cost	Total
50	12.80 x 5.49	705,917	$ 4,600	$ 28,500	$33,150
100	18.29 x 5.49	1,440,886	8,800	42,400	51,200
150	22.86 x 5.49	2,251,288	13,000	58,500	71,500

12. Pump Out Accessories for Flygt Cutter Pump

Base unit, mast, brackets and 15.2 cm pipe	$ 400
Labor for installing in manure storage	120
Electrical service to storage	500
	$1,020

Use $1,000

APPENDIX I

Labor, Electrical and Tractor Use Cost to Compare Annual Cost of Three Manure Management Systems

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Consider 50, 100, and 150 cow confinement stall barn systems

Daily Spreading Trials

1. Daily spreading trials at AFRC -- annual labor for hauling 2.4 kilometers round trip --

	COWS		
	--------- Hours ---------		
Trial	50	100	150
DS 1	228	322	415
DS 2	255	345	434
DS 3	212	297	383
DS 4	206	284	362
DS 5	186	269	351
DS 6	181	260	338
	1,268	1,777	2,283
Average	211	296	381

NOTE: Only 50% of total time required for barn cleaner to load spreader was assigned to labor input for manure handling. Assumed other 50% of labor directed to other chores. However, tractor use time would have to include total time required for barn cleaner to load spreader.

Trial	50% of Loading Time (Minutes)
DS 1	0.250
DS 2	0.230
DS 3	0.214
DS 4	0.213
DS 5	0.217
DS 6	0.217
	1.341
Average	0.2235 minutes/cow/day

2. Tractor use hours over and above labor hours assigned:

$$\frac{0.2235 \text{ mins./cow/day} \times 365 \text{ days/year}}{60 \text{ mins./hour}} = 1.36 \text{ hours/cow/year}$$

3. Annual tractor use hours to haul and spread manure:

Cows	Hours Labor	Additional Tractor Hours	Total Tractor Hours
50	211	50 x 1.36	279
100	296	100 x 1.36	432
150	381	150 x 1.36	585

(continued)

4. Labor to lubricate and service gutter cleaner and spreader (daily spreading operation).

Cows	Gutter Cleaner	Spreader	Total	Total Hours Per Year
	Hours Per Week			
50	1/2	1	1-1/2	78
100	3/4	1	1-3/4	91
150	1	1	2	104

5. Annual electrical energy cost to operate gutter cleaner at $.06/kWH (clean barn once each day).

Cows	Motor kW	Meters of Chain		Chain Velocity Meters/ Minute		Hours Per Year	kW Draw*		kWH Rate	Cost Per Year
50	1.49	76.81	÷	3.66	÷	60 x 365	x 1.7	x	$.06	$ 13
100	2.24	140.21	÷	3.66	÷	60 x 365	x 2.6	x	.06	36
150	3.73	203.61	÷	3.66	÷	60 x 365	x 4.3	x	.06	87

*Assumes:

- o 3 phase 220 volt electrical service
- o motor operates at full load current
- o power factor of 75%

LIQUID MANURE HANDLING -- Using an Above-Ground Tub Type Storage, Flygt Cutter Pump for Mixing, Transferring Manure to Storage, Agitation of Manure in Storage and Loading Manure Out of Storage to a 8.5 Cubic Meter Martin Spreader

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1. Annual electrical cost (@ $.06/kWH) to operate gutter cleaner to deliver manure to reception pit (clean barn twice daily).

50 cows	$ 26
100 cows	72
150 cows	174

(continued)

2. Annual electrical cost to operate cutter pump (14.92 kW, 3 phase) in reception pit for mixing manure and transferring to storage.

   o 3 day reception pit storage
   o agitate daily and pump to storage every third day

Cows	Agitation Mins/Day*	Transfer to Storage Mins. Every Third Day**	Annual Operating Hours***	kWH Rate	Annual Cost
50	25	7	166	$.06	$133
100	50	14	333	.06	268
150	75	21	499	.06	401

*Approximate time period gutter cleaner operates.

**Capacity taken at 1.42 cubic meters per minute.

***The 14.92 kW, 3 phase Flygt pump draws 13.4 kW.

3. Annual labor cost to operate cutter pump in reception pit for mixing manure and transferring to storage.

   o 3 day reception pit storage
   o agitate daily and pump to storage every third day

Cows	Agitation Mins/Day*	Transfer to Storage Mins. Every Third Day**	Annual Hours	Hourly Rate	Annual Cost
50	3	20	59	$5	$295
100	3	20	59	5	295
150	3	20	59	5	295

*Time allowed only to check pump once daily.

**Time allowed for any final agitation necessary, setting pump in pump out mode and returning to agitation mode. Assumes automatic low level pump cut-off.

(continued)

4. Manure Input to Storage

- 54.25 kg produced per cow day including 5.90 kg dry sawdust bedding and the average dry matter sampled in the ram hopper was 17.3%.

- Assume Flygt cutter pump can agitate and transfer manure to storage at 14% dry matter:

$$\frac{54.25\text{ kg} \times .173}{.14} = 67.04\text{ kg per cow to storage}$$

- Water added in reception pit per cow day (@ 1 kg/liter):

$$67.04\text{ kg} - 54.25\text{ kg} = 12.79\text{ liters}$$

- Density of manure going into storage:

$$\begin{array}{l} 54.25\text{ kg @ } 993\text{ kg/m}^3 \times 81\% = 804 \\ 12.79\text{ kg @ } 1{,}000\text{ kg/m}^3 \times 19\% = \underline{190} \\ \qquad\qquad\qquad\qquad\qquad\qquad\quad 994 \end{array}$$

  Use 994 kg/m^3

- Manure input to storage per cow day:

$$\frac{67.04\text{ kg}}{994\text{ kg/m}^3} = 0.067\text{ m}^3$$

- Manure input to storage annually:

50 cows	1,230 m^3
100 cows	2,460 m^3
150 cows	3,690 m^3

5. Manure Out of Storage (two unloadings)

- Assume Flygt cutter pump can agitate and pump to spreaders 12% dry matter manure.

- Manure loaded out:

  50 cows $$\frac{1{,}230\text{ m}^3 \times .14}{.12} = 1{,}435\text{ m}^3 = 1{,}425\text{ M. tons}$$

  100 cows $$\frac{2{,}460\text{ m}^3 \times .14}{.12} = 2{,}870\text{ m}^3 = 2{,}850\text{ M. tons}$$

  150 cows $$\frac{3{,}690\text{ m}^3 \times .14}{.12} = 4{,}305\text{ m}^3 = 4{,}275\text{ M. tons}$$

- Required water added annually to storage from precipitation or other sources to create 12% dry matter manure (cubic meters):

  50 cows 1,435 - 1,230 = 205 m^3
  100 cows 2,870 - 2,460 = 410 m^3
  150 cows 4,305 - 3,690 = 615 m^3

(continued)

6. Reference Data From SS Trials

- Martin spreader model S-1668 used and the average payload was 7,617 kg (7.62 M. tons).
- Average spreading time was 2.364 minutes/load.

7. Loading Time Required by Flygt Pump

- Model FP 3152, 14.92 kW, 3 phase.
- With 12% manure solids, 6.10 meters vertical lift and 15.24 meters of 15.2 cm pipe, capacity 4,463 liters/min. or 4.46 m^3.
- Pump should load 8.50 m^3 spreader in 1.91 minutes.
- Allow an average of 4 minutes per load to accommodate shifting pump from the agitating to pumping modes as required.

8. Hauling Time Required

- Based on 13.15 kilometers per hour hauling (trials SS1 -- SS8-B), 11.02 minutes would be required to haul each load 2.4 kilometers round trip.

9. Total Cycle Time Per Load

Loading	4.00	minutes
Hauling	11.02	minutes
Spreading	2.36	minutes
	17.38	minutes cycle time

10. Annual Man Hours to Load and Haul Liquid Manure From Storage

Cows	M. Tons of Manure Out of Storage	Average M. Ton Per Load	Number Loads	Cycle Time Mins./Load	Annual Man Hours
50	1,425	7.62	187	17.38	54
100	2,850	7.62	374	17.38	108
150	4,275	7.62	561	17.38	162

11. Annual Tractur Use Cost to Haul and Spread Manure With 93.25 kW Tractor With Operational Costs (Including Fuel) of $.221/kW Hour

Cows	Total Hours	Tractor kW	Cost/kW Hour	Annual Cost
50	54	93.25	.221	$1,114
100	108	93.25	.221	2,228
150	162	93.25	.221	3,342

(continued)

12. Annual Man Hours to Agitate Manure in Storage With a Flygt Cutter Pump

			Cows		
			50	100	150
			------ Hours ------		
o Move cutter pump from reception pit to storage and return to reception pit.					
	50 cows	2 moves	2		
	100 cows	4 moves		4	
	150 cows	6 moves			6
o Attending pump every 2 hours during agitation to change vertical and horizontal position of nozzle. Allow 10 minutes for each check.					
	Cows	Hours Agitation Each Unloading			
	50	16	2.7		
	100	24		4	
	150	32			5.3
			4.7	8.0	11.3

13. Total Annual Man Hours to Agitate, Load and Haul Liquid Manure From Storage

Cows	Agitation	Loading & Hauling	Total
50	5	54	59
100	8	108	116
150	11	162	173

14. Annual Electrical Cost to Operate Cutter Pump (14.92 kW, 3 Phase) In Storage For Agitation and Pumping Manure Out of Storage

Cows	Agitation Hours	Pumping Hours	Total Hours	kWH Rate	Annual Cost
50	32	6	38	$.06	$ 31
100	48	12	60	.06	48
150	64	18	82	.06	66

15. Annual Labor Cost to Lubricate and Service Gutter Cleaner, Cutter Pump and Spreader @ $5/Hour

		Hours Per Year				
Cows	Gutter Cleaner Hours/ Week	Gutter Cleaner	Pump	Spreader	Total Hours	Annual Cost
50	1/2	26	4	20	50	$250
100	3/4	39	4	24	67	335
150	1	52	4	28	84	420

(continued)

SEMISOLID MANURE HANDLING -- Using an Agway roof-covered storage, Ralco ram for transferring manure to storage, and a 33.57 kW steer-skid loader to load manure out of storage to an 8.5 cubic meter Martin spreader.

1. Annual electrical cost (@ $.06/kWH) to operate gutter cleaner to deliver manure to ram (clean barn twice daily so ram can generally keep up with barn cleaner).

50 cows	$ 26
100 cows	72
150 cows	174

2. Annual electrical cost (@ $.06/kWH) to operate manure ram (3.73 kW motor). Ram operates 0.01509 hours/cow day at Agway Farm Research Center.

Cows	Annual Operating Hours		kW Draw*		kWH Rate	Cost Per Year
50	275	x	4.3	x	$.06	$ 71
100	550	x	4.3	x	.06	142
150	825	x	4.3	x	.06	213

*Assumes:

- 3 phase 220 volt electrical service
- motor operates at full load current
- power factor of 75%

3. Summary of Trials SS-1 Through SS-8B

Trial	Kilograms Manure/Cow Day Weighed Out of Storage	Minutes Per M. Ton Loading	Kilometers Per Hour Hauling
SS-1	49.13	0.47	11.62
SS-2	45.04	0.94	13.57
SS-3A	45.68	0.88	13.94
SS-3B	45.68	0.95	14.31
SS-4A	50.71	1.01	11.44
SS-4B	50.71	0.95	11.91
SS-5A	51.26	1.43	11.51
SS-5B	51.26	1.09	11.83
SS-6A	49.58	1.15	15.50
SS-6B	49.58	1.05	12.99
SS-7A	52.75	0.99	15.00
SS-7B	52.75	1.08	18.80
SS-8A	51.21	1.08	10.90
SS-8B	51.21	1.17	10.67
	696.54	14.24	183.96
Average	49.75	1.01	13.14

(continued)

4. Manure Weighed Out of Roof-Covered Storage Annually

49.8 kilograms/cow/year	50 cows	908 M. tons
18,163.3 kilograms/cow/year	100 cows	1,816 M. tons
18.16 M. tons/cow year	150 cows	2,724 M. tons

5. Reference Data From SS Trial

- Martin spreader model S-1668 used and the average pay load was 7,617 kg (7.62 M. tons).
- Average spreading time was 2.364 minutes/load.

6. Loading Time With 33.57 Kilowatt Steer-Skid Loader

- From #3 above, 1.01 minutes per M. ton required to load manure with steer-skid loader.
- 7.72 minutes required to load one load (7.62 M. tons).

7. Hauling Time Required

- Based on 13.14 kilometers per hour hauling (trials SS1-SS8B), 11.02 minutes required to haul each load 2.4 kilometers round trip.

8. Total Cycle Time Per Load

Loading	7.72	minutes
Hauling	11.02	minutes
Spreading	2.36	minutes
	21.10	minutes cycle time

9. Annual Man Hours to Load and Haul Semisolid Manure From Storage

Cows	M. Ton of Manure Out of Storage	Average M. Ton Per Load	Number Loads	Cycle Time Mins./Load	Annual Man Hours
50	908	7.62	119	21.1	42
100	1,816	7.62	238	21.1	84
150	2,724	7.62	357	21.1	126

10. Annual Tractor Use Cost to Load Manure With a 33.6 kW Steer-Skid Loader With Operational Costs (Including Fuel) of $.221/kW Hour

Cows	M. Tons of Manure Out of Storage	Loading Time Per Ton	Tractor Hrs. Per Year	Annual Cost
50	908	1.01 mins.	16	$119
100	1,816	1.01 mins.	31	230
150	2,724	1.01 mins.	46	342

(continued)

11. Annual Tractor Use Cost to Haul and Spread Manure With 93.25 kW Tractor With Operational Costs (Including Fuel) of $.221/kW

- o Tractor use hours equal total labor hours for unloading and handling manure.

Cows	Total Hours	Tractor kW	Cost/kW Hour	Annual Cost
50	42	93.25	$.221	$ 866
100	84	93.25	.221	1,733
150	126	93.25	.221	2,599

12. Annual Labor Cost to Lubricate and Service Gutter Cleaner, Ram and Spreader @ $5/Hour

	Hours/Week		Hours Per Year				
Cows	Gutter Cleaner	Ram	Gutter Cleaner	Ram	Spreader*	Total Hours	Annual Cost
50	1/2	1/2	26	26	20	72	$360
100	3/4	3/4	39	39	24	102	510
150	1	1	52	52	28	132	660

*Assumes one man hour per day to lubricate spreader during the unloading period and eight man hours each six months to clean and service spreader for storage.